SPE JOURNAL

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Complete PROGRAM and ABSTRACTS — See Contents

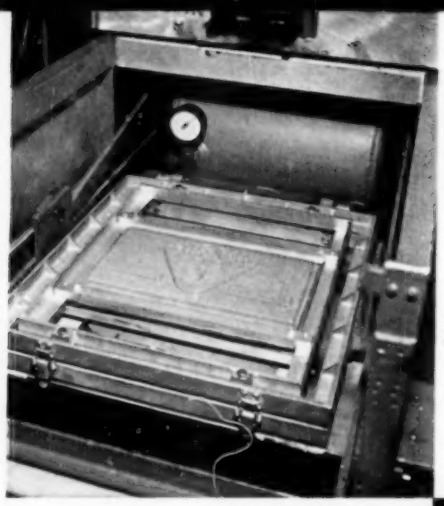
Science

Performance

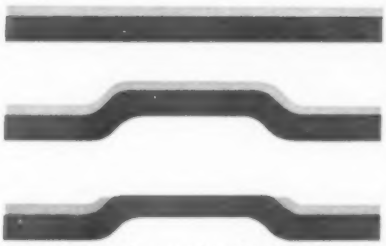
Engineering

Here's news about Butyrate plastic...

Duplex Butyrate sheet yields 2-color signs that by-pass usual decorating...the sheet itself provides the second color



Duplex sheet is formed in the same manner as regular Butyrate sheet for signs.



Duplex Butyrate sheet consists of a single thickness with thick and thin layers of Butyrate in two different colors.

The versatility of Tenite Butyrate as a plastic material for signs gains added recognition with the development of duplex sheet. By taking advantage of the ingenious construction of this new sheet, the creative sign designer and sign builder can produce 2-color effects without use of lacquers or inks.

In essence, duplex Butyrate plastic sheet consists of a heavy layer of one color under a thin layer of a second color. The sheet is produced by extruding and laminating one layer of colored plastic directly upon another layer of a different contrasting color. For example, a duplex sheet for forming a representative 4- by 6-foot sign panel might have a heavy layer 0.090-inch thick and a thin layer 0.010-inch thick.

After the sheet has been formed into a sign panel or element, with the thin layer on the appearance side, the color of the heavy layer may be quickly exposed by sanding away the thin layer from the raised surfaces of the sign face. The choice of color combinations will be determined by the effects desired, the specific application, the use (or the non-use) of backlighting, and the esthetic preference of the individual sign designer.

For information on availability of duplex Butyrate sheet, write to the Plastics Division, EASTMAN CHEMICAL PRODUCTS, INC., KINGSPORT, TENNESSEE, or to the sales office nearest you.

After forming, the thin layer of color is sanded away from certain raised areas to expose the second color underneath.

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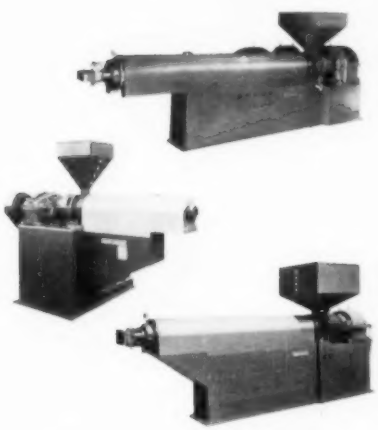

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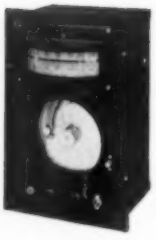

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An international scientific and educational organization of more than 8,000 individual members devoted to the development and dissemination of technical information in the fields of research, design, development, production and utilization of plastics materials and products. The Society is incorporated under the laws of the State of Michigan.

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SPE JOURNAL
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H. A. Doolittle, Manager
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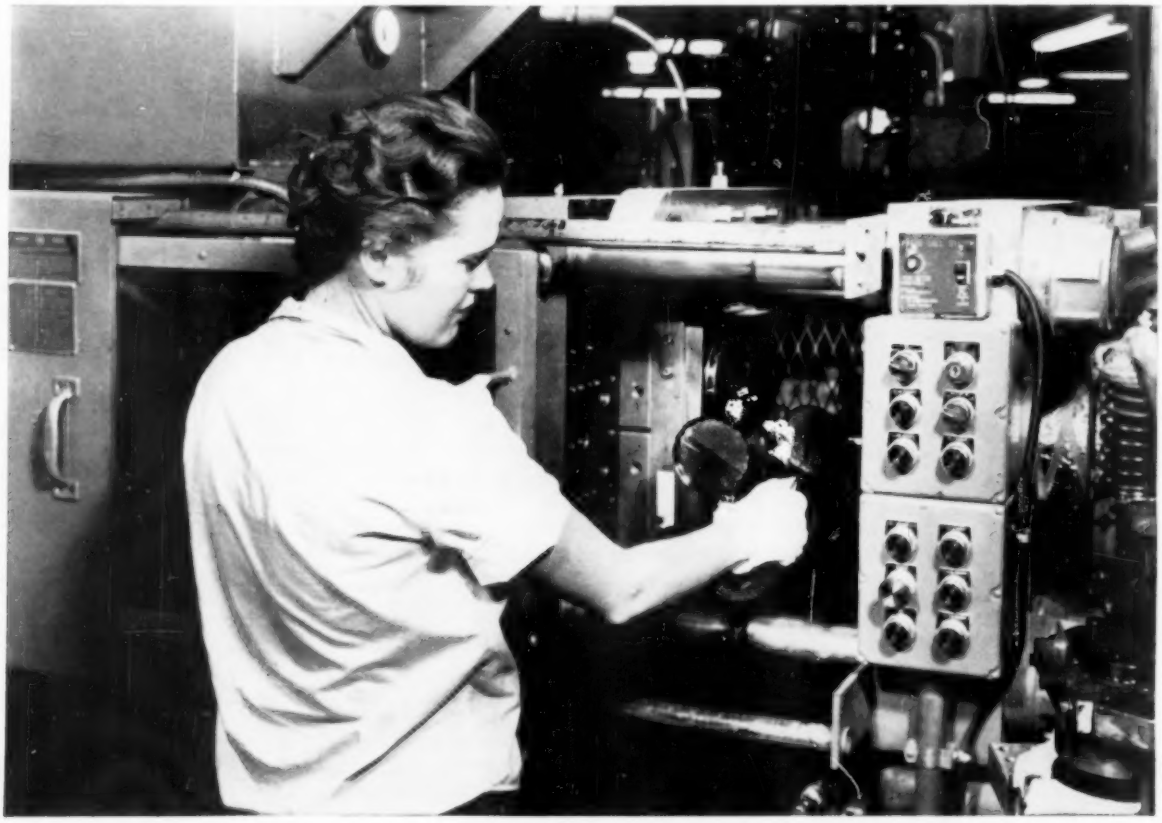

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Progress Through Basic Research

The Society of Plastics Engineers is unique among technical and professional societies. Membership is as vertically integrated as you can get, bridging the gap between the study of the union of simple molecules into long chains—polymer chemistry—to processing and fabricating of plastics. For proof, look at the program for the 17th Annual Technical Conference on page 25.

During the past 5 years, technology and *utilization* of plastics have advanced rapidly. The key to continuing progress is research. This is where the industry emphasis should be, and this is where SPE should play a leading role. There is evidence of a beginning trend in this direction. For example, SPE's Education Committee under the leadership of Dr. C. C. Winding, Cornell University, has recently completed a survey of universities to determine how many offer courses in polymer chemistry, published in the December SPE Journal; an SPE Committee has attempted to spearhead the establishment of a Plastics Institute, a facility where research not directed toward specific commercial objectives would be done; the Annual Technical Conferences provide excellent opportunities to report on original polymer research.

While much has been done, there is more still left to do. Thomas H. Risk, of the research and engineering staff of The Ford Motor Co., told the Regional Technical Conference at Newark last November, "We do not need nor want super plastics with ultra superior properties and high cost. The needs of the automotive industry are for new working plastics which have good overall properties at moderate cost." These are also the needs of other industries. They are needs which will be fulfilled only through basic research in the polymer field. Stimulation of such research is a task requiring motivation of the most altruistic nature, directed by leadership of the highest order.

There is already evidence of much greater activity in enhancing the fortunes of the plastics industry through basic polymer research. One local Section of the American Chemical Society has just recently established a polymer chemistry group, affiliated with that Section; a symposium on inorganic polymers is to be held at the University of Nottingham next July, and the month after there will be an international symposium on macromolecular chemistry held in Montreal. The Baltimore-Washington Section of SPE sponsored an eminently successful regional Technical Conference in December 1959 on the subject of polymer stability.

The engineering work to document heat resistance, strength, and stress resistance of existing and new plastics materials is necessary and always will be. Before a new material can realize its full potential of applications, it must be thoroughly characterized. But to rally the industry to the challenge of the future, the emphasis must be on original research.

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TONS CLAMP
PER SQUARE FOOT
OF FLOOR SPACE

Standard engineers designed the Automolder 100 ton 3 ounce injection molding machine to meet the needs of the plastic industry. Full hydraulic clamp assures faster mold set-up . . . full range electrical controls save operator time . . . compact design with self contained hydraulic system occupies less space. The K3-100-50 is the first of 5 new Automolders to be introduced during our Golden Anniversary.

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U.S.I. POLYETHYLENE NEWS

A series of advertisements for plastics and packaging executives by the makers of PETROTHENE® polyethylene resins

Packaging Notes

Disposable aprons of polyethylene-coated perforated and embossed paper were tested in the galleys of a rig by an offshore oil drill company to determine their utility. The aprons are said to protect against grease spatterings, and withstand the normal soiling encountered in meal preparation. The expense of handling and transporting soiled cloth aprons back to the mainland and laundry costs are eliminated by the disposable apron.

Storage drums of conventional polyethylene, accepted by FDA for use with foods, can now be obtained in 20-, 32- and 55-gallon sizes with or without dust covers. Air-tight polyethylene covers and steel closure rings are available for the 55-gallon size, also.

According to the manufacturer, drums are clean, white, lightweight and quiet; have excellent impact resistance; nest for storage; will handle most jobs of stainless steel drums, yet cost less. Other applications include storing supplies, emergency water, sterile linens and clothing, and chemicals.

One-Gallon Jug fabricated of conventional polyethylene has pouring spout set off-center to allow a large carrying handle on top. A tail on the handle permits using the little finger to get a tighter hold.

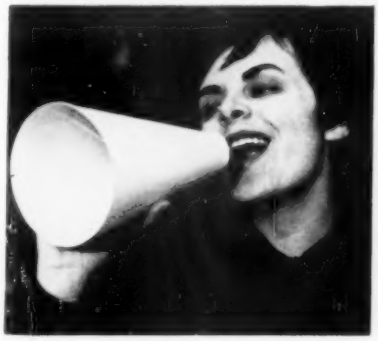
According to the producer, this redesigned jug, which is the same price as a previous model made by the company, has a stronger spout and body and is more stable. Closures are claimed to be skip-proof and leak-proof.

New end label for polyethylene bread wrap claimed to have exceptional adhesive qualities requires only moderate heat for positive closure. The coating is activated at approximately 150°F. which is 40° lower than the temperature needed by most other heat-activated end labels. (The heat from a cigarette is said to be sufficient.) This quick-melt coating eliminates melted or pinhole burned polyethylene.

U.S.I. Sees Usage of Polyethylene Up 10 Per Cent In 1961

Increases Anticipated in Many Market Areas

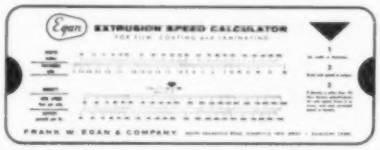
"In 1961, polyethylene will regain much of the sales momentum that characterized its dynamic growth in the late 1950's," forecasts Vincent D. McCarthy, Director of Plastic Sales of the U.S. Industrial Chemicals Co.



Sports Megaphones Injection Molded Of Polyethylene

Megaphones for sports fans are being injection molded of a U.S.I. PETROTHENE polyethylene resin by an Ohio firm. According to the company, PETROTHENE 208 resin was chosen because of its uniformity, and because it provides good gloss and durability, flows better than competitive materials, and gives better than average results with dry coloring.

Available in a variety of colors with contrasting hot-stamped collegiate emblems, the megaphones are reported to withstand constant squeezing and handling and a wide range of weather conditions.



Free Slide Chart Offered

A handy extrusion speed calculator for film, coating and laminating is available from a manufacturer of extrusion coaters. With this slide rule, the extrusion capacity required for a specific web speed, width and coating thickness can be quickly determined.

Polyethylene film will be a leading factor in increasing polyethylene usage by 10% in 1961, according to Vincent D. McCarthy, U.S.I.'s Director of Plastics Sales.

U.S.I., manufacturer of PETROTHENE resins, is the world's second largest producer of polyethylene.

Mr. McCarthy predicts a rise in usage approaching 10% for 1961, indicating that a number of fast-growing markets will make it possible.

The demand for film and sheeting of conventional polyethylene, for example, is expected to increase to 465 million lbs. in 1961 compared with the 400 million lbs. used last year. Spurred by wider use of inplant automatic polyethylene packaging equipment, this material has made steady inroads in breadwrap, produce, textile, and other fields. Automatic equipment in use is typified by the See-Safe machine, with which even outsize products such as card tables and bolts of cloth can be custom-packaged efficiently in polyethylene.

Additional conventional polyethylene, perhaps as much as 75 million lbs., can be expected to go into coating this year. Polyethylene coated milk cartons will lead the growth in the fast moving extrusion coating fields.

Blow Molding To Gain

According to Mr. McCarthy, blow molding, now a 50-million lbs.-per-year market, will climb faster in '61 and eventually rank with injection molding (now consuming 250 million lbs. of conventional polyethylene yearly). He sees a shift developing from low-density to medium-density polyethylene in this field, but feels the 1961 sales upturn will be shared by linear polyethylene.

Pipe and wire and cable insulation are among other markets for conventional polyethylene which are each expected to contribute an increase of about 5% in usage to the '61 sales picture.

U.S.I.

Series VI, No. 1

POLYETHYLENE PROCESSING TIPS

HOW TO DETERMINE OPTIMUM BLOW-UP RATIO

In blown film extrusion, blow-up ratio is the ratio of the diameter of the film "bubble" to the diameter of the extruder die. It's much easier to measure the width of the lay-flat tube after it has passed through the nip rolls than the diameter of the inflated bubble. And since the two are related by simple geometry, blow-up ratio can be calculated easily from the formula:

$$\text{Blow-up ratio} = 0.637 \times \frac{\text{lay-flat width}}{\text{die diameter}}$$

The best possible balance of film properties for a given polyethylene resin can be obtained with a 2:1 to 2.5:1 blow-up ratio. This recommendation is based on studies at U.S.I.'s Polymer Service Laboratories, combined with field experience of U.S.I.'s Technical Service Engineers.

Effect on Specific Film Properties

In the U.S.I. studies, six general-purpose film-grade polyethylene resins were extruded under comparable conditions at blow-up ratios of 1:1, 1.5:1, 2:1, 2.5:1, 3:1, and 3.5:1. The properties of these resins varied over a rather wide range. Yet, as blow-up ratio was increased, the effect on specific properties was similar for all six resins:

Transmittance increased 12 to 16 units (Fig. 1). PETROTHENE® 112, for example, had a 60% transmittance at 1:1 blow-up ratio and 72% transmittance at 3.5:1.

Gloss, measured at a 60° angle, increased 1.2 to 2.5 units (Fig. 2). The average was 7.1% at 1:1 blow-up ratio and 9.3% at 3:1.

Haze decreased significantly (Fig. 3). Average decrease was 3.5 to 4.5 units.

Impact strength improved (Fig. 4).

FIGURE 1

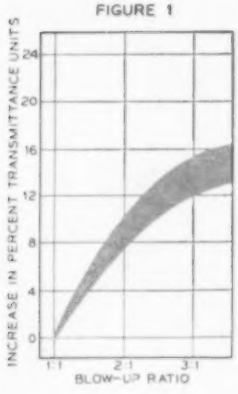
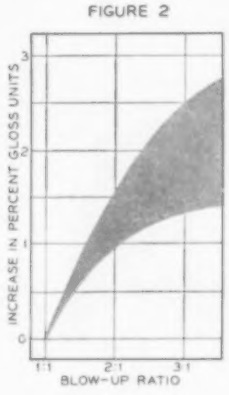


FIGURE 2



While these tests seem to indicate 3:1 or higher as an optimum blow-up ratio, this is not the case. Note how other essential properties are affected by an increase in blow-up ratio:

Straight line tear, the tendency of film to tear in a straight line, is reduced significantly.

Elmendorf tear strength decreases significantly above a 2:1 blow-up ratio.

Yield strength decreases slightly.

Break point increases in the transverse direction and decreases in the machine direction.

Tendency to wrinkle may be a serious problem above a 2.5:1 blow-up ratio.

How To Increase Blow-Up Ratio

Because film lay-flat width is almost always predetermined, blow-up ratio is ordinarily increased by using a smaller die diameter. True, this results in a slight decrease in output; however, increasing screw speed will usually compensate for most of this decrease.

What Blow-Up Ratio Should You Use?

Extruders now producing blown film at a blow-up ratio below 2:1 should consider increasing it if they desire improved optical properties and higher impact strength. Also, companies entering the field should consider blow-up ratio before deciding which size dies to buy.

Of course, other factors may be involved. If you have questions on specific problems, we suggest you seek advice from U.S.I. Technical Service Engineers.

FIGURE 3

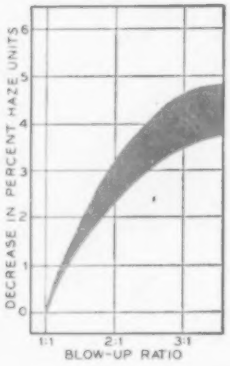
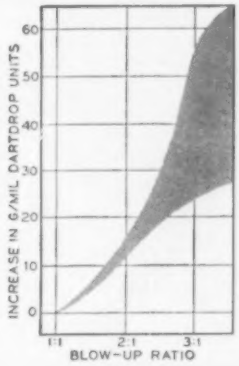


FIGURE 4



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Letters

Interest in Multiple Level Injection Molding

Dear Sir:

I read with lively interest the article by Messrs. Csaszar and Saulino titled "Multiple Level Injection Molding" which appeared in the September 1960 issue (page 1009). We would like a reprint.

In addition, I would like to know if the holder of the pertinent patent, Mr. Saulino, would be disposed to offer the French license to it, and under what conditions. The patent number is U. S. 2,571,766.

G. Fabre
Connaissance des Plastiques
Paris, France

Mr Saulino's Reply

We would be interested in exploring any such possibilities directly with the parties concerned. Inquiries should be directed to Mr. Theodore Saulino, Royal Associates, 2165 Morris Ave., Union, N. J.

Dear Sir:

Please send a reprint of the article Multiple Level Injection Molding.

Oscar Quereilhac
Technical Dept. Manager
Nibo Plast
Ramos Mejia, Argentina

D-20 Fading Standards

Dear Sir:

We read with interest your review of vinyl plastics test methods in the October issue (1129) and would appreciate more information on the use of plastics fading standards in light resistance tests. Are these standards available as yet, or could we obtain details on their preparation?

Lt. Col. John Butchkosky
Assistant Director
U. S. Army Prosthetics Res. Lab.
Walter Reed Army Medical Center

Author's Reply

The fading standards that you are inquiring about will be completely described in an ASTM Recommended Practice that is to be issued soon. This practice has been passed by D-20 and is being presented to the Society for acceptance.

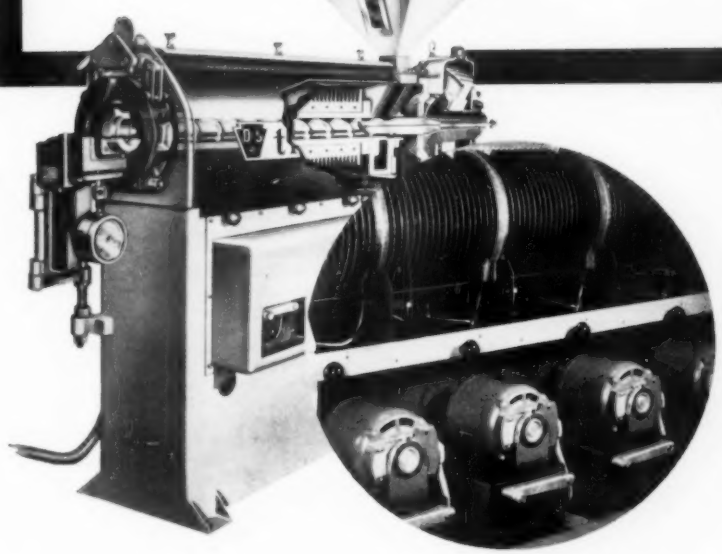
As this may take another month or two, I am requesting D. A. Hurst, chairman of the subcommittee investigating this method, to send you the latest draft of this practice for your study.

J. B. DeCoste, *Chairman*
ASTM Committee D-20 on Plastics

SOONER OR LATER

PVC PIPE PRODUCERS WILL NEED thermatic*

COOLING CAPACITY



*Patented

Thermatic® Series extruders have enough cooling capacity to permit:

(A) High heat application at the feed section heat zone for fast melt and low horsepower consumption . . . with

(B) Ample cooling along the barrel to prevent scorching while holding precise stock temperature . . . and

(C) Higher head pressure with stable stock temperature provides thorough mixing and higher quality pipe.

Proper cooling can make a big difference to Pipe Producers. Get the facts on

THERMATIC COOLING CAPACITY

D-S thermatic

DAVIS-STANDARD
Division of
FRANKLIN RESEARCH AND DEVELOPMENT CORPORATION
17 WATER STREET, MYSTIC, CONNECTICUT

NAME _____ TITLE _____

COMPANY _____

STREET _____ STATE _____

PRECISION EXTRUSION CONTROL IS OUR BUSINESS

TENITE DEVELOPMENT LABORATORY DOINGS AND FINDINGS

THE CHALLENGE THAT IS BLOW MOLDING

Compared with other engineering achievements, blow-molded polyethylene bottles were launched commercially at a relatively high level of sophistication. Tin cans, for example, were first made by skilled plumbers, who cut sheet metal with shears and soldered it together at the rate of 6 cans an hour. By contrast, blow molding evolved simply as a combination of two older processes: pipe extrusion and thermoforming. This combination immediately eliminated cooling of extrudate and reheating prior to forming.

Eastman's plastics laboratories have devoted considerable work to the development of machine innovations which will permit smoother and faster blow molding . . . and for good reason! By 1965, it has been estimated, detergent producers alone will demand 2 billion bottles annually. Rigid quart-size bottles can be quickly blown from high-density (linear) polyethylene such as Tenite Polyethylene 3420—melt index 0.8, density 0.95. Low-density polyethylene such as Tenite Polyethylene 831—melt index 1.1, density 0.913—is used for the ever-popular squeeze bottle and also for blow-molded doll bodies and other toys.

One of the first innovations made by our Tenite Development Laboratory upon acquiring a blow molding machine for test work was to put a restriction in the parison die. This restriction was created by building up the mandrel as shown by the shaded area of the sketch below. Long experience with pipe extrusion strongly indicated that forcing the molten polyethylene through the restriction would serve to destroy premature orientation and thereby help eliminate non-uniform parisons and weld lines. Subsequent tests have verified this idea.

But better and higher production has not been the only challenge to face resin producer and blow molder. There has also been the need for resins exhibiting special properties and characteristics. In squeeze-bottle applications, for example, Tenite Polyethylene enjoys special popularity because of its superior "snap back." Also much in demand have been resins which produce the very glossy surfaces generally favored for containers. No sooner are these available than—you've guessed it—comes a cry from fabricators for a polyethylene that will give a dull finish, for products such as doll bodies. Work on problems like these can consume almost as much manpower as developing resins with greater resistance to stress cracking.

And speaking of stress cracking . . . wouldn't life be sweet if only oils and greases did not promote stress cracking in polyethylene? We wonder sometimes whether Nellie Bly encountered any such difficulties when she invented and patented the steel oil barrel in 1900.

No need, however, for resorting to a steel drum or even a tin can or glass bottle just to package oil or grease. Containers blow molded of Tenite Butyrate, a cellulosic plastic, not only offer superior resistance to these compounds but also exhibit sparkling clarity and great toughness.

Now, about Nellie Bly . . . yes, she was the newspaper woman who in 1889 went around the world in less than 80 days (72 days, 6 hours, 11 minutes). Admittedly, we don't have any Nellie Blys. But we do have research engineers, development engineers, service engineers and technical representatives who know a good deal about plastic processing. They resemble Nellie only in the amount of travel they do, keeping on top of the latest problems encountered by plastic processors.

We offer you not only the service of a fine staff but also a wide selection of low-, medium-, and high-density Tenite Polyethylene formulations. If you are not completely satisfied with some phase of your operation and think a special Tenite plastic might help, why not discuss your problem with a nearby Tenite representative, or write to EASTMAN CHEMICAL PRODUCTS, INC., *Plastics Division,* KINGSPORT, TENNESSEE.

TENITE®

plastics by Eastman

Letters

Bound Journals

Dear Sir:

It has occurred to me that you might wish to follow the example set by many technical periodical publishers, and offer at a nominal price a binder especially designed to hold twelve issues of the Journal. Such a binder could be designed so that it would be easy for members to keep their copies of the Journal neatly bound on a year-to-year basis. The binder offered each year could have numbers such as 1960, 1961, etc. hot stamped in gold or other color for quick identification. The Society might even be able to make a modest profit on the sale of such binders.

Merton E. Hill
Gossett and Hill Co.

Dear Sir:

Please advise if the Journal is available in hard backed bound editions and the cost of same to members of the Society.

R. W. Russell
Engineering Department
Westinghouse Electric Corp.

Editor's Note

It is expected that in the next month or so, appropriate binders will be offered to members and subscribers.

Under the Horizon

Dear Sir:

In the Newsletter there is an item which ends up by saying "Also on the horizon—and soon, one-shot epoxy resin systems that can be cured by heat alone."

One-shot epoxy resin systems that can be cured by heat alone have been available for at least four years, to my knowledge.

What else is new?

B. Kellam
Ontario

Member in Tokyo

Dear Sir:

Announcement of my election to membership in the Society as a Senior Member is of the greatest pleasure to me. I look forward with the greatest interest to a long and vivid association in the various affairs of the Society.

Kaneyoshi, Nomaguchi
Tokyo, Japan

NEW FROM ENJAY

HEXYL ALCOHOL

● A raw material for the chemical industry

SPECIFICATIONS FOR HEXYL ALCOHOL

Purity, as Hexyl Alcohol (Wt. Per Cent)	min. 98.0
Specific Gravity (20/20° C.)	min. 0.819
	max. 0.821
Acidity as Acetic Acid (Wt. Per Cent)	max. .001
Color (Pt—Co)	max. 10
Water (Wt. Per Cent)	max. 0.10
Carbonyl Number (Mg KOH/g)	max. 0.2
Distillation: °C.	
Initial	min. 149
Dry Point	max. 158
Appearance	Clear and free of suspended matter

Hexyl Alcohol is another product resulting from the vast research and development program being conducted by Enjay to serve the chemical industry. Of special interest to vinyl plastic compounders are the phthalate esters of Hexyl Alcohol which exhibit high efficiency and good solvating properties, making them ideal as calendering aids. Hexyl Alcohol has many other promising applications as a raw material for *flotation agents, lubricant additives, degreasing fluids, brake fluids* and *agricultural chemicals.* Enjay also markets decyl, tridecyl and isooctyl alcohols as chemical raw materials. Whenever you specify Enjay, quick, dependable deliveries are provided from conveniently located distribution points. For more information, write to 15 West 51st Street, New York 19, N. Y.

EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

ENJAY CHEMICAL COMPANY

A DIVISION OF HUMBLE OIL & REFINING COMPANY

ENJAY
PETROCHEMICALS

SPE EDUCATIONAL EXHIBIT ON PLASTICS IN BUILDINGS TO OPEN APRIL 15, 1961

The Society of Plastics Engineers first educational and technical traveling exhibit, "Plastics—A New Dimension in Buildings", has been announced by Armand G. Winfield, Chairman of the SPE Plastics in Buildings Professional Activity Group of which the exhibit is a project.

Opening in Springfield, Massachusetts on April 15, 1961, the exhibit will travel to some 16 major North American cities for 30-day showings during 1961-1963.

This educational exhibit is designed to disseminate technical information to architects, builders, contractors, interior designers and students.

Among the cities where this educational exhibit will be shown in museums or universities will be New York, Washington, Minneapolis, Dallas, Seattle, Los Angeles, Birmingham, Memphis, Columbus, Toronto, etc.

This technical exhibit will include some 30 individual units devoted to the use of plastics in buildings. It will show the plastics materials as well designed and integrated products designed for use in buildings in four major areas: 1. Background and introduction; 2. Constructural; 3. Interior Furnishings; 4. Decorative and Aesthetic Uses.

The exhibits will show the materials, illustrate the best existing uses of these materials; and project ideas for future usage. The exhibit will take up about 2500 square feet of display area.

Among the companies sponsoring this educational and technical exhibit are:

Allied Chemical Corp.
American Biltrite Rubber Co.
Architectural Plastics Corp.
Barclite Corp. of America
Carlon Products Corp.
Celanese Corp. of America
Cohn-Hall Marx and Co.
Duriron Corp.
Enjay Chemical Co.
General Electric Co.
Gilman Brothers Co.
Herman Miller, Inc.
Hooker Chemical Co.
Kalwall Corp.
Marbon Chemical Co.
Panelmade Corp.
Sturgis Posture Chair Co.
Swedlow Plastics Co.
Union Carbide Plastics Co.
Wasco Products, Inc.
Wilson Engineering Co.

A one-day SPE Regional Technical Conference on the same subject "Plastics in Buildings" will be held in Springfield, Massachusetts on April 20th, during the first showing of the exhibit. The Conference will be sponsored by the SPE Western New England Section with the cooperation of the Plastics in Buildings PAG.

Additional companies desiring to display materials or products can be accepted as sponsors for a limited period.

Further information is available from Armand G. Winfield, Chairman SPE Plastics in Buildings PAG, P. O. Box 332, Hazardville, Conn.

SPE EDUCATIONAL EXHIBIT "PLASTICS— A NEW DIMENSION IN BUILDINGS"

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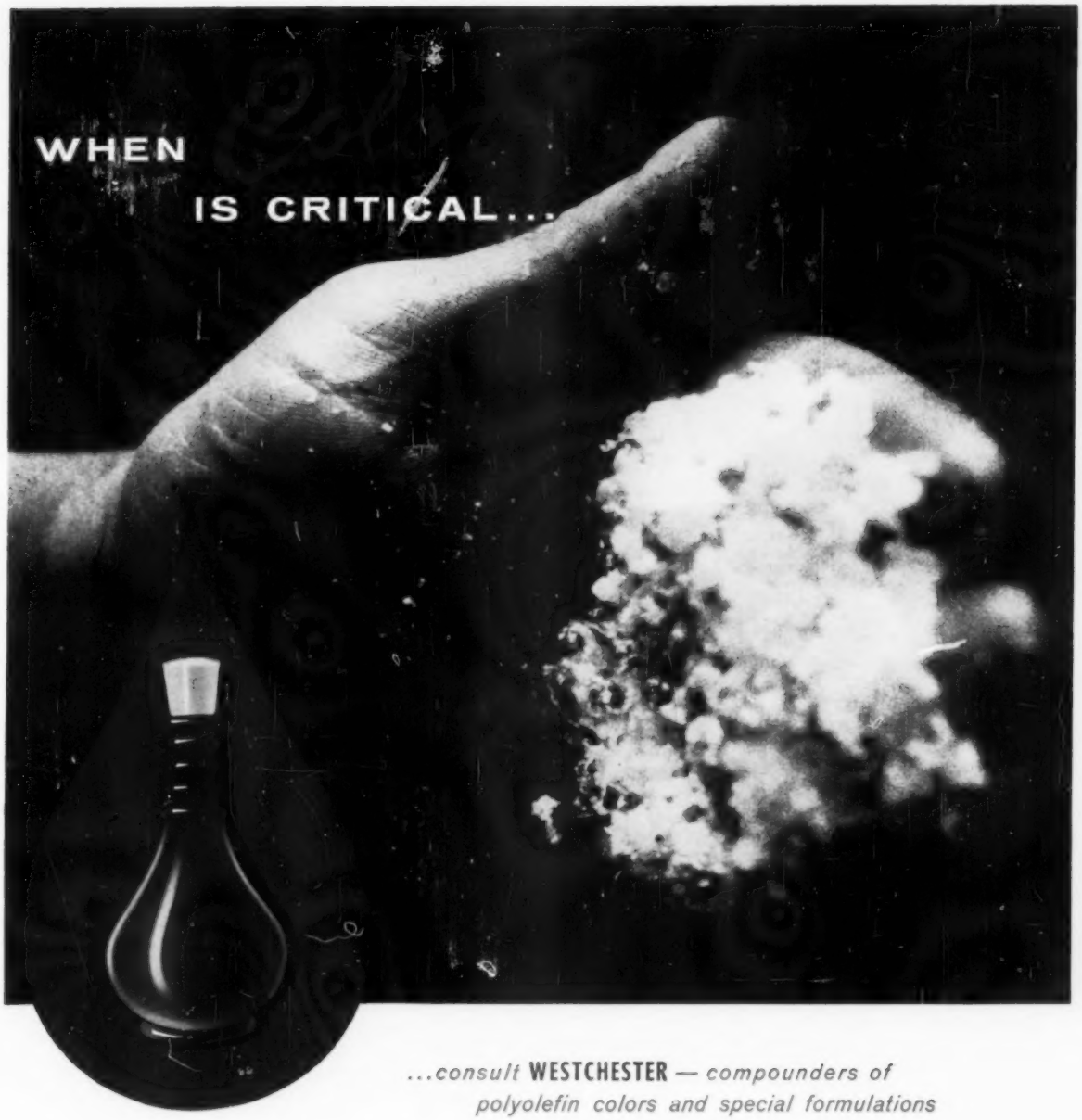

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EXPERIENCED HANDS at Westchester guide your order through production. Every color formulation is scientifically tested for uniform dispersion, stability, desirable temperature, flow characteristics . . . and resistance to degradation, migration and leaching

For detailed information – backed by 14 years of service to the thermoplastics industry – consult Westchester about any color or formulating problem involving polyolefins.

The new FDA certified Westchester colors are now available. Approved for food, drug and cosmetic packaging – These colors are supplied with a registration number, attesting FDA approval of the pigments!

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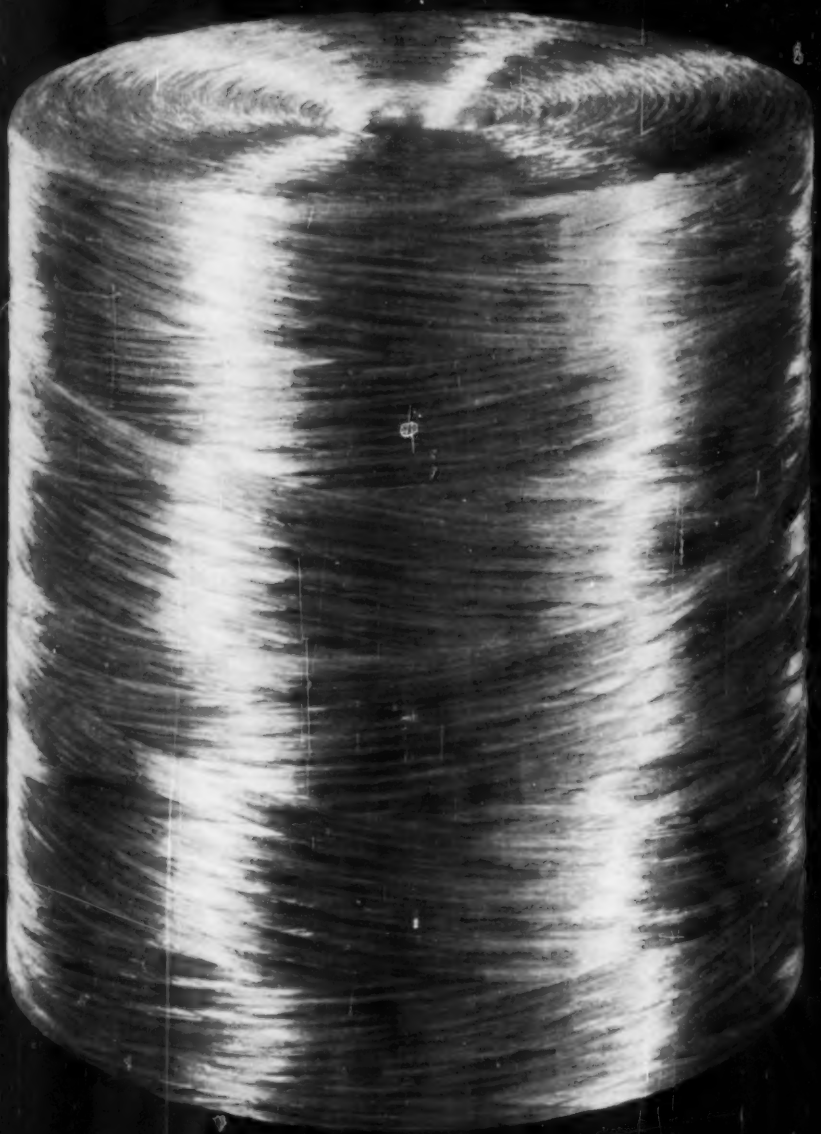
FERRO'S Brand New UNIROVING



The industry's finest roving, long used *exclusively* for production of Ferro Uniformat and Unirove reinforcing materials, is now available to thermosetting molders. To our friends who have waited for this day, after "trial runs" while we were expanding production facilities, we want to express sincere thanks. And we promise to deliver the same *high quality, consistently uniform* roving they found so satisfactory in their tests. If you are interested in such material, we invite you to try UNIROVING. Write for samples, specifications, prices.

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Nashville 11, Tenn. . . . Huntington Beach, California

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SPE JOURNAL NEWSLETTER

reading time
1 minute

17th ANTEC

SPE's Annual Technical Conference will feature papers on thermodynamic and flow properties of polymers, as well as high temperature applications. Of particular note is a study on thermodynamic charts for polyethylene. Filament reinforced plastics, printed circuits and statistics are among applications covered in 28 technical sessions. For the complete program and abstracts of papers see page 25.

Plastics for Safety

New plastic contributions to industrial and highway safety: A ¼-inch thick molded polyethylene basket liner protects power line workers resisting over 50,000 volts. A fluorescent nylon cap protects valve stems of double wheel truck tires, prevents the stem from pulling into the tire when one tire of the pair goes flat.

Plastics in Space

The Air Force reports that plastics sent into space as films, foams and coatings may actually gain strength when exposed to ultraviolet radiation and extreme vacuum. Breaking the molecular chain results in crosslinking instead of degradation if oxygen is lacking, tests show. Polypropylene and polyethylene terephthalate were best plastics in simulated space tests.

Pre-Preg Standards

The Society of the Plastics Industry has issued three new standards for testing preimpregnated materials for reinforced laminates to judge production characteristics and performance. The tests measure resin and volatile content, flow characteristics and gel time.

Ultrasonic Welding

A novel method of joining plastic films, ultrasonic welding, is offered by several equipment suppliers. Plain or metallized films may be joined by highly localized action and without heat.

new technical ideas • trends • industry news

IMPACT!

This is a "warhead". It's the front end of a carrier which darts through a pneumatic tube system at speeds up to 20 mph, and is subject to frequent shocks and impact. There's a story behind the choice of LEXAN® polycarbonate resin for this new design . . .

Formerly, destinations were set by contacts along the entire body of the carrier. Engineers of Airmatic Systems Corporation, Saddle Brook, New Jersey, reasoned that if all the control elements could be fitted into a small impact- and wear-resistant head, the rest of the carrier could be designed for easy maintenance and quick replacement. Many plastics had the required dielectric strength, but none could measure up to LEXAN resin's combination of good electrical properties, excellent dimensional stability and extremely high impact strength. LEXAN resin actually withstands over 12 foot-pounds per inch of notch — an impact strength attained by no other plastic!

The new warhead is injection-molded of black LEXAN resin by Berkeley Engineering & Manufacturing Co., Berkeley Heights, N. J. Now when wear and tear take their toll, the transparent carrier body is easily replaced, since it has no control elements. Also, body length can be varied to suit customer needs, and carrier weight is reduced. Printed circuits and compactly arranged brushes and control plates are used. The new design is more attractive, more practical, less costly. And—LEXAN resin warheads have proved in field tests to last longer than the old control units.

G.E. LEXAN polycarbonate resin has raised the quality of many designs to new levels. It has been reduced in price approximately 40% over the past year! Can this tough, new thermoplastic help you? Send for design literature.

LEXAN®
Polycarbonate Resin

GENERAL ELECTRIC

Chemical Materials Dept., Section SPE-11, Pittsfield, Mass.

SCIENCE ENGINEERING

PERFORMANCE

An Invitation to Come to

Washington in January 1961

Society of Plastics Engineers, Inc.

17th ANNUAL TECHNICAL CONFERENCE

January 24, 25, 26, 27, 1961 (Tues. through Fri.)

Shoreham and Sheraton-Park Hotels, Washington, D. C.

AN APPLICATION FOR HOTEL ROOM RESERVATION WILL BE MAILED TO YOU UPON RECEIPT OF YOUR ADVANCE REGISTRATION.

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Will Your Wife Accompany You to Washington?

☐ Yes ☐ No

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☐ Primary Materials Suppliers
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☐ Heavy Machinery Manufacturers
☐ Light Machinery & Access. Equip.
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☐ End User. Describe _____
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REGISTRATION FEES†

SPE MEMBER	☐ $15.00
NON MEMBER	☐ $30.00
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SPECIAL FUNCTIONS

Tuesday Luncheon	☐ $ 4.50
Wednesday Luncheon	☐ $ 4.50
Thursday Banquet	☐ $10.00
Total Enclosed:	$_____

No Refunds After January 20, 1961

This space for Committee Use Only
Date Received: _____
Amount _____
Acknowledged _____

† Includes cost of preprint of papers.

SPI Individual Members May Register at $15.00

17th ANTEC Program Shapes Up

Program innovations, including a special panel of four guest lecturers and technical sessions on newest aspects of the plastics industry, will be featured at the 17th Annual Technical Conference. See pages 25 to 39 for complete program and abstracts of papers being presented.

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17th ANNUAL TECHNICAL CONFERENCE

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...with 2 New RCI EPOTUF Epoxy Hardeners

● You can control the degree of hardness or flexibility of your cured epoxy systems—when you use RCI EPOTUF Hardeners 2611 and 2613.

By blending the two, in conjunction with an epoxy resin, a formulator can easily and dependably produce systems that will result in hard, flexible or resilient products.

Each of the hardeners may be used individually . . . both are for room-temperature curing of epoxy resins.

EPOTUF Hardener 2611 is recommended in a simple 1:2 ratio with epoxy resins. It hardens the epoxy in 10 minutes to a hard, yet resilient, blush-free plastic. Because of its low viscosity, it handles easily and can be highly filled.

EPOTUF Hardener 2613 is generally used in a convenient 1:1 ratio with the epoxy resins. It cures rapidly with an unusually low exotherm. The flexible, blush-free system it provides has up to 100% elongation in a cured epoxy with total recovery.

Tensile strength of these systems will range from 2,000 psi to 14,000 psi.

Perhaps the controlled flexibility possible with these versatile new EPOTUF Hardeners can improve your epoxy systems. Write to RCI for complete technical information.

RCI *Creative Chemistry . . . Your Partner in Progress*

REICHHOLD

Synthetic Resins • Chemical Colors • Industrial Adhesives • Phenol • Hydrochloric Acid • Formaldehyde • Phthalic Anhydride • Maleic Anhydride
Ortho-Phenylphenol • Sodium Sulfite • Pentaerythritol • Pentachlorophenol • Sodium Pentachlorophenate • Sulfuric Acid • Methanol

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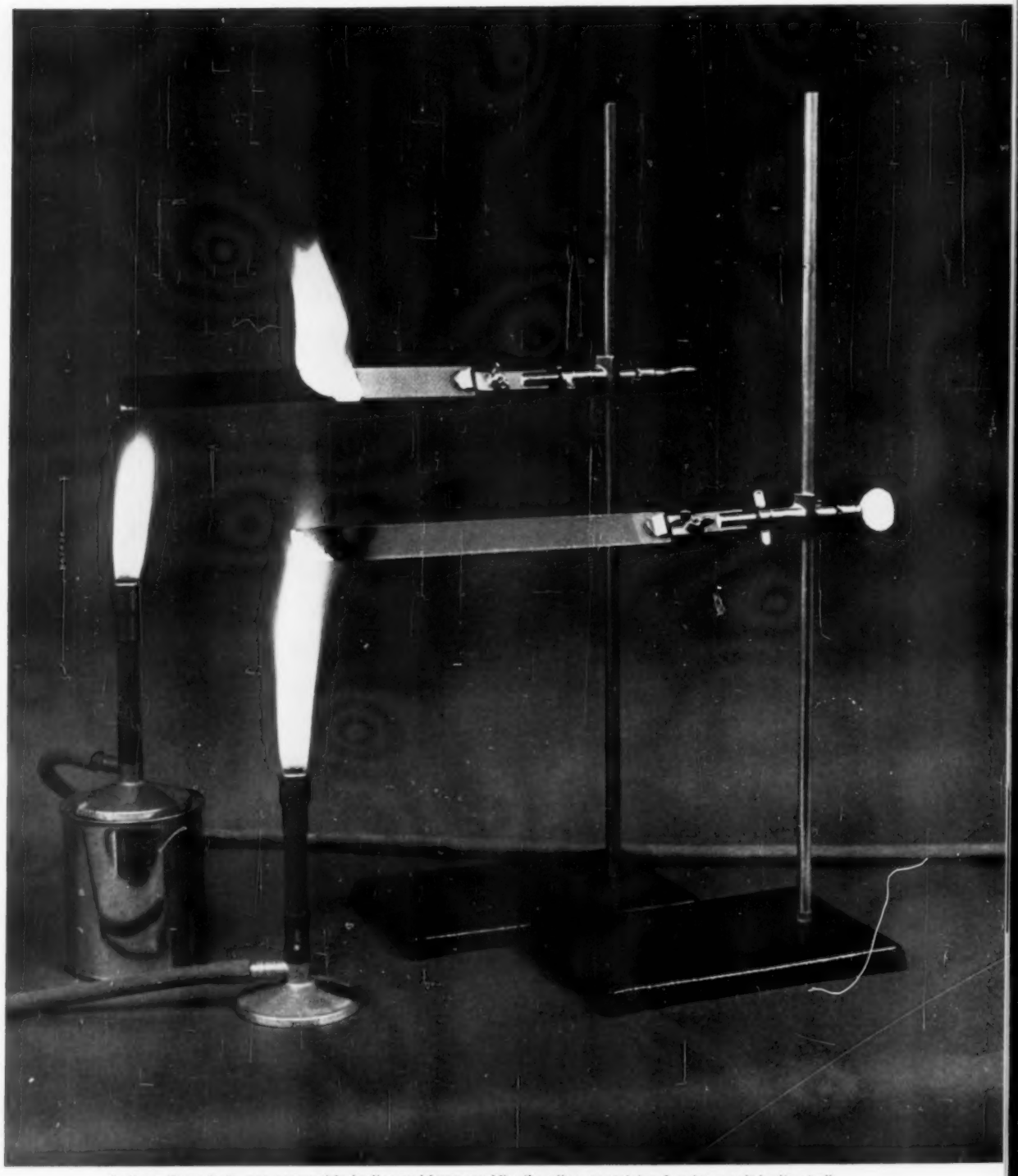


In these flame tests, one epoxy strip ignites and burns rapidly; the other, containing Aroclor, won't ignite at all.

AROCLORS are COMPATIBLE with virtually all plastics resins • polyvinylidene chloride • cellulose acetate propionate • polyvinyl acetate • chlorinated rubber • ethyl cellulose • benzyl cellulose • polystyrene • nitrile rubber • phenolics • polyamides • epoxies • acrylics • urethanes • polyesters • polyethylene • nitrocellulose • polyisobutylene • styrene-butadiene • polyvinyl butyral • polyvinyl chloride • cellulose acetate butyrate

HOW TO "BUILD IN" HIGH RESISTANCE TO FIRE AND CHEMICALS WITH LOW-COST AROCLOR® PLASTICIZERS AND RESIN EXTENDERS

AROCLOR *chlorinated* polyphenyls—liquid or solid—offer remarkable *inertness*. They don't burn, evaporate, hydrolyze, or oxidize. They defy strong acids and alkalies. They blend readily with nearly all resins, solvents, plasticizers, and other plastics-compounding ingredients. You can choose from 13 standard AROCLORS—to impart outstanding flame retardance, chemical resistance, and other desired properties to your plastics compounds and protective coatings . . . *at low cost.*

NONBURNING EPOXIES

Aroclors are fully compatible with epoxy resins. Combined with a small amount of antimony oxide, they produce *nonburning* compositions. Aroclor 5460 yields epoxies with optimum compressive strength. Aroclor 1221 greatly improves flexibility.

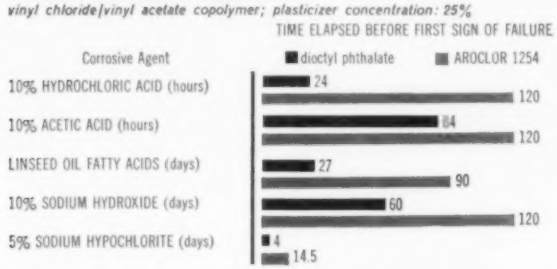
	AMINE-CURED EPOXIES		PHTHALIC ANHYDRIDE-CURED EPOXIES	
formulation	**control**	**modified**	**control**	**modified**
liquid epoxy resin	100	100	100	100
diethylenetriamine	13	13	...	...
phthalic anhydride	...	...	75	75
antimony oxide	...	5	...	5
DMP 30 (Rohm & Haas)	...	...	0.1	0.1
AROCLOR 1260	...	15	...	...
AROCLOR 5460	...	...	...	15
properties				
compressive strength, *psi*	43,000	38,150	23,400	40,700
flexural strength, *psi*	20,100	22,100	16,900	19,000
heat distortion, °C.	117.5	92	143	135
FLAMMABILITY—*inches per minute* (ASTM D635-56T)	0.82	NON-BURNING	0.6	NON-BURNING

EXTENDERS FOR PVC

Aroclors are especially effective as secondary plasticizers or extenders for polyvinyl chloride. Aroclor 1262, used 1:3 with dioctyl phthalate, sharply reduces migration to nitrocellulose lacquers. All Aroclor compounds can be used to improve the chemical resistance of vinyl chloride–vinyl acetate coating formulations.

TYPICAL CHEMICAL RESISTANCE*

vinyl chloride/vinyl acetate copolymer; plasticizer concentration: 25%



Plotted from independent evaluation data by the Northwestern Paint and Varnish Production Club** (The Official Digest, Nov. 1955). Conclusion: **"The Aroclor 1254 had the best all-around chemical resistance."

SELF-EXTINGUISHING POLYETHYLENE

Aroclor 5460 gives self-extinguishing, low-density polyethylene *with minimum effect on tensile strength or "memory."* Aroclor 5460 substantially improves heat stability, too, compared with other common flame retardants.

LOW-DENSITY POLYETHYLENE

formulation	**control**	**modified**
polyethylene	100	70
antimony oxide	....	10
AROCLOR 5460	....	20
properties		
melt index	1.96	6.2
% elongation	655	650
tensile strength, *psi*	2130	1710
yield strength, *psi*	1395	1300
FLAMMABILITY—*inches per minute*	7.1	SELF-EXTINGUISHING

***NEW BOOKLET** gives the facts about "Aroclor Plasticizers"... **compounding procedures, performance data, property tables, specific formulas.** It tells how versatile AROCLORS could be your answer for better compounds at lower cost. Mail the coupon today*

Monsanto

Monsanto, maker of more plasticizers than any other company, provides these benefits to customers:

precisely right plasticizer systems

mixed-shipment savings

able technical help in depth

MONSANTO CHEMICAL COMPANY
Organic Chemicals Division
Department 2822-V, St. Louis 66, Missouri

Please send me:

( ) PL-306, "AROCLOR PLASTICIZERS"

( ) CS-14, "AROCLOR PLASTICIZERS IN EPOXY RESINS"

I'm interested in Aroclors for.....resins.

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TITLE.....COMPANY.....

STREET.....

CITY.....ZONE.....STATE.....

Another new

B.F.Goodrich Chemical *raw material*

NOW

make these and other products of newly available...

Absson

Absson—a versatile acrylonitrile-butadiene-styrene material—becomes the newest addition to the growing line of quality plastic materials from BFG Chemical.

Absson has superior flow characteristics for molding and extruding—gives high gloss, excellent surface finish, and fine detail to finished products. You can count on its uniform high quality.

Production and application knowledge as well as samples are available. Write Dept. NG-1, B.F.Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

Absson
ABS MATERIALS

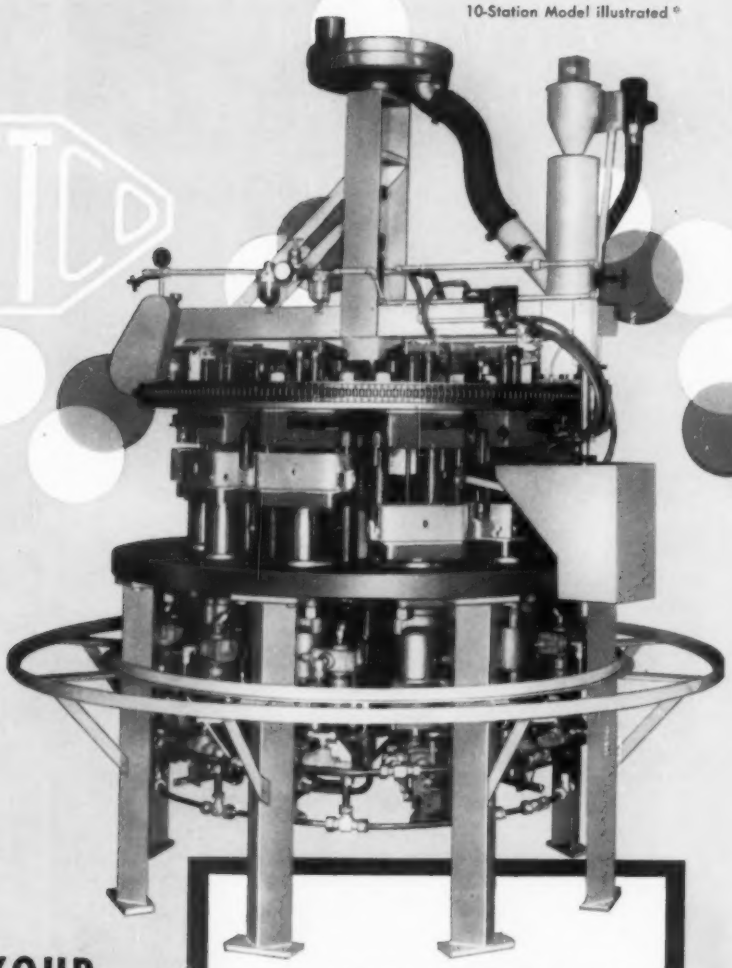
B.F.Goodrich Chemical Company
a division of The B.F.Goodrich Company

B.F.Goodrich

GEON vinyls • HYCAR rubber and latex • GOOD-RITE chemicals and plasticizers

NE-BUTTCO

10-Station Model illustrated *



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Society of Plastics Engineers, Inc.

17th ANNUAL TECHNICAL CONFERENCE (ANTEC)

Special Events

Tuesday—January 24, 1961, 12:00 Noon—Blue Room, Shoreham

EDUCATION COMMITTEE LUNCHEON

Speaker: Dr. E. W. Comings
Dean of Engineering, University of Delaware

Tickets—**$4.50, each,** *available at registration desk*

•

Wednesday, January 25, 1961, 12:00 Noon—Blue Room, Shoreham

MEMBERSHIP LUNCHEON

Presentation of 1960 Annual Report
Introduction of SPE 1961 Officers
Annual Business Meeting of the Society

Tickets—**$4.50, each,** *available at registration desk*

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Thursday Night, January 26, 1961—Cotillion Room, Sheraton Park Hotel

BANQUET

featuring

cocktails (no host)—6:30 P.M.
dinner —7:30 P.M.
Entertainment —9:30 P.M. **(see page 37)**

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PAG's and Committee Meetings—see next page

Registration Information

Lower Lobby, Shoreham Hotel

Mon. — 1:00 P.M.-8:00 P.M.
Tues. — 8:00 A.M.-8:00 P.M.
Wed. — 8:00 A.M.-6:00 P.M.
Thurs.— 8:00 A.M.-5:00 P.M.
Fri. — 8:00 A.M.-Noon

Registration Fees

SPE Members*	$15.00
Non-Members	$30.00
Student	$ 5.00

* Under a reciprocal agreement, SPI individual members admitted to ANTEC at SPE member rate

Meetings During ANTEC

- *Committee Meetings*
- *PAG Meetings*
- *Council Meetings*
- *Past Presidents*

All events at the Shoreham Hotel, except the Banquet and otherwise noted events, which will be held at the Sheraton-Park Hotel.

PROFESSIONAL ACTIVITY GROUPS (PAG)

Afternoon technical sessions will adjourn at 3:15 P.M. PAG business meetings will be held beginning at 3:30 P.M. each day, following the technical sessions.

Tuesday, January 24, 1961
3:30-5:30 P.M.

PAG	*Room*
Extrusion	Terrace Banquet
Plastics in Electrical Insulation	Park
Reinforced Plastics	West Ballroom
Standards for Reporting Properties	North
Thermosetting Molding	Main Ballroom
Coloring of Plastics	South

Wednesday, January 25, 1961
3:30-5:30 P.M.

Injection Molding	Main
Casting and Plastics Tooling	North
Plastics in Building	West Ballroom
Plastics in the Automotive Industry	South
Polymer Structure	Terrace Banquet

Thursday, January 26, 1961
3:30-5:30 P.M.

Finishing	Park
Forming	South
Metal Mold Design and Construction	West Ballroom
Vinyl Plastics	Main Ballroom
Blow Molding	Terrace Banquet

COMMITTEES

Committee	*Time*	*Room*
Sunday, January 22, 1961		
Executive	10:00 A.M.	President
Councilmen's Reception	5:00 P.M.	Martin's Suite
Monday, January 23, 1961		
1960 Council	9:15 A.M.	Park
Plastics Institute	10:00 A.M.	North
Council Luncheon	12:30 P.M.	Club
Editorial Advisory Bd.	7:00 P.M. (Dinner)	Club
Finance	6:30 P.M. (Dinner)	Pres. Martin's Suite
Tuesday, January 24, 1961		
1961 Executive	9:30 A.M.	Pres. Martin's Suite
Meetings	2:00 P.M.	East
Education	2:00 P.M.	Foyer B
Engineering Board	4:00 P.M.	Club
Administrative Board	8:00 P.M.	North
Wednesday, January 25, 1961		
Committee to Study Engineering Displays	8:00 A.M.	Club
Publications	9:00 A.M.	North
PAG Executive	10:00 A.M.	South
1961 Council	2:00 P.M.	Park
Membership and Credentials; Regional Section, Stud, Chmn.	4:00 P.M.	Foyer B
Technical Volumes	4:00 P.M.	East
Technical Program	5:00 P.M.	Foyer A
Sections and Section Presidents	8:00 P.M.	Park
Thursday, January 26, 1961		
Past Presidents	10:00 A.M.	North
Advisory Board	(luncheon at noon)	South
Inter-Society Relations	2:00 P.M.	North
Editors and Authors, Vol. III	2:00 P.M.	East
Friday, January 27, 1961		
PAG Officers	9:30 A.M.	North
Joint 17th & 18th ANTEC Executive	12:00 Noon (luncheon)	Club

HEADQUARTERS

17th ANTEC Committee — West

Press Room — Green

Ladies' Hospitality (Tuesday through Friday)—Tamerlane

OTHER EVENTS

Moderators and Speakers Meals: — Club
Breakfasts (Tuesday through Friday)—8:00 A.M.
Luncheons (Tuesday through Thursday)—12:00 P.M.

Complete Program

17th Annual Technical Conference

including

outline of technical sessions and abstracts of papers

All events at the Shoreham Hotel, except the Banquet and otherwise noted events, which will be held in the Sheraton-Park Hotel

Tuesday Morning—January 24, 1961
9:00 to 11:15 A.M.

Session 1—Test Methods

MODERATOR, J. B. DeCoste, *Bell Telephone Laboratories*
Location: Main Ballroom

1-1. Determination of Heat Distortion Characteristics of Rigid Materials by Means of a Torsional Apparatus

Norman L. Perry, *Argus Chemical Corp.*

The torsional apparatus commonly used for measurement of low temperature flexibility of elastomers may be easily adapted to the measurement of heat distortion characteristics of rigid materials. By measuring angular deflection as a function of temperature at constant stress, a sharp rate of increase is noted at a temperature which may be called the heat distortion temperature, T_s.

Using this technique, the effect of vinyl chloride compounding materials on heat distortion characteristics have been determined. Effect of stabilizer choice, plasticizer addition, resin molecular weight, and comonomer content is shown.

1-2. Evaluation of Extruded High-Impact Polystyrene for Refrigerator Door Liners

D. A. Davis, J. V. Schmitz and R. S. Hagan, *General Electric Co.*

The use of high-impact polystyrene, thermoformed into door liners, has become universally accepted during the past five years. There remains, however, a divergence of opinion on what properties are required of a satisfactory material (ANTEC Paper 65, 16th ANTEC, January 14, 1960). This paper discusses an evaluation program used by a major refrigerator manufacturer to approve new materials for acceptance. Properties discussed include conventional mechanical and impact strength, time-dependent mechanical behavior, chemical properties, engineering tests and processing behavior. A motion picture is presented to illustrate the various testing methods used.

1-3. Microscopic Examination of Decorative Laminates

Paul E. Willard, John N. Jessup and Jerry Kreinik, *Chemicals & Plastics Division, Food Machinery and Chemical Corp.*

Techniques have been developed for the microscopic examination of sections of decorative laminates. The preparation of specimens is described, including cutting, polishing and preparing for microscopic observation. Details of the photomicrographic techniques used are also presented. Full color photomicrographs of sections of typical decorative laminates, such as melamine-formaldehyde, polyester and diallyl phthalate types, have been prepared, and conclusions regarding structural characteristics of these laminates are shown. By the examination of polished sections of laminates it is possible to determine the structural components used in the production of a given laminate.

1-4. Pitfalls in Predicting the Performance Characteristics of High Density Polyethylene

V. J. Folt, *B. F. Goodrich Co.* and R. J. Ettinger, *Goodrich Gulf Chemicals Inc.*

High density polyethylenes prepared by various manufacturers possess different properties, though tests may yield identical values. The utility of melt or flow index measurements in predicting processing behavior is limited in scope because of shear effects and melt fracture. Determination of true melt curves at several temperatures is necessary to determine which polymer will yield the highest output.

Tuesday Morning—January 24, 1961
9:00 to 11:15 A.M.

Session 2—Extrusion

MODERATOR, Paul N. Richardson, *E. I. du Pont de Nemours & Co., Inc.*
Location: Terrace Banquet Room

2-1. Extrusion Plastification

L. F. Street, *Welding Engineers, Inc.*

A series of tests on plastifying granules or powder feed were conducted. An opinion has been widely held that as the material plastifies against the surface of the barrel, it is scraped off by the flight and the plasticized material mixed in with the unfused granules or powder, thus rapidly filling the channel with a mixture of plastified and unmelted material which was then suitable for treatment according to the normal extrusion action of the screw. Results of this test indicate that this theory is incorrect. An alternate explanation is presented and illustrated.

2-2. Application Guide to Extruder Pressure Measurements

R. L. Eckman and G. A. Pettit, *Barber-Colman Co.*

Sealed, direct-contact type melt pressure transducers have been used on laboratory extruders and are being increasingly employed on production machines with conventional industrial instrumentation. The new transducers have high sensitivity and rapid response and provide information not otherwise obtainable. A two-function transducer to measure both melt temperature and pressure is presently under development.

2-3. Flow Patterns in a Non-Newtonian Fluid in a Single-Screw Extruder

W. D. Mohr, J. B. Clapp, and F. C. Starr, *Polychemicals Department, E. I. du Pont de Nemours & Co., Inc.*

Flow patterns in the channel of a screw extruder have been investigated in a study utilizing a model extruder with stationary screw and a rotating, transparent barrel. Photographs of flow streamlines at conditions over the full range of output restriction are presented for a non-Newtonian fluid. A technique employing photographs of particle tracers was used with the same apparatus to permit quantitative measurement of velocity profiles with both a Newtonian and a non-Newtonian fluid.

2-4. Heating Capacity Limitations of Extruder Screws

B. H. Maddock, *Union Carbide Plastics Co.*

This paper treats the problems involved in achieving high stock temperatures for applications such as extrusion coating of paper or other substrates with polyethylene. It covers extension of work reported at the 16th ANTEC in January, 1960, in which it was concluded that the use of extra long metering sections gave marked improvements in mixing efficiency and product homogeneity at considerably higher screw speeds and output rates than normally considered practicable. By suitable adjustment of screw speed and back pressure, fairly high stock temperatures can be achieved at high output rates and good quality levels.

Tuesday Morning—January 24, 1961
9:00 to 11:15 A.M.

Session 3—Electrical Insulation

MODERATOR, Alexander E. Javitz, *Electro-Technology (formerly Electrical Manufacturing)*
Location: Park Room

3-1. A Study of Polymers Applicable to Insulation Systems

K. A. Torossian and S. L. Jones, *General Electric Co.*

In recent years thermosetting polymeric systems have been used extensively as binders in electrical insulation and composite plastic structures with excellent success. However, such properties as post-cure gassing, thermal stability, and high-temperature bond strength have always been stumbling blocks for the insulation engineer. Experience has shown that these properties can ultimately affect the dielectric endurance of an insulation when subjected to high voltage stresses. The above mentioned problems are generally controlled by the organic binders present in the insulation. Test methods have been developed whereby the behavior of the polymers under certain conditions can be predicted, thus increasing the effectiveness of the design engineer.

3-2. Moisture Resistant Coatings for Class B Printed Circuitry

Arthur F. Ringwood, *General Electric Co.*

Solventless coating systems are desired for both systems applications. In each case and particularly in that of the Class B, the most highly recommended commercially available coatings were tested along with proprietary formulations for compliance with the ten day moisture resistant test requirement of MIL-E-5272B. The systems tested comprised, essentially, epoxy resins, polyurethanes, and epoxy-polyurethanes combinations.

Since the coatings were to be used on the production line, processability, preferably by a dip method, was of prime importance. Therefore, on the basis of this requirement alone, practically all the vendors' materials were eliminated. None could be degassed without the addition of solvents or thinners to cut the viscosity. Few coated uniformly or without excessive run-off in the curing oven. However, several of the most promising were evaluated in order to obtain the data for use in future designs of less critical performance.

3-3. Improved Reliability for Printed Circuits with Protective Coatings

Edward W. McGuiness, *Laboratory for Electronics, Inc.*

This paper is concerned with improved reliability of printed circuits by coating the finished circuit with a protective, water resistant and chemical resistant insulating coating. There is a brief general discussion of the various copper-clad laminates together with a discussion of design requirements relative to necessary spacing to protect against voltage creep and conductor size to give adequate current capacity. This includes the results of tests at room temperature, after exposure to humidity and thermal shock and would compare both coated and uncoated boards. The effect of contamination upon the electrical properties of the coated and uncoated boards will be described as will the effects of high altitude.

3-4. Mica as a Reinforcing Material for Printed Circuit and Terminal Board

E. G. Dingman, *Research Director, The Macallen Co., Inc.*

Mica papers used as a reinforcing material for laminates in combination with epoxy resins give a material equal to or superior to other types of reinforcement. Laminates were found to have moduli of elasticity in the range of 10 to 15 million psi. All laminates were found to be self extinguishing. The coefficient of expansion is near that of copper. Electrical properties are excellent and in the case of muscovite paper are almost unchanged after exposure to high humidity. The material appears to be highly satisfactory for electrical uses and is competitive in price with other types of laminates.

Tuesday Morning—January 24, 1961
9:00 to 11:15 A.M.

Session 4—Reinforced Plastics (I)

MODERATOR, George Lubin, *Grumman Aircraft Corp.*
Location: West Ballroom

4-1. Simplified Analysis of Filament Reinforced Plastic Pressure Vessels

R. J. Brown, Jr., *Aerojet-General Corp.*

Filament reinforced plastics present new problems in structural analysis for design engineers who are familiar

with the application of homogenous materials. Article familiarizes the designer with the basic considerations for non-isotropic filament design analysis. In filament winding, a major consideration is the proper orientation of filaments which is compatible with the methods of fabrication.

4-2. Service Life Estimates for FRP Structures on Basis of Accelerated Fatigue Tests

R. P. Molt, *Stanray Corp.*

It is frequently desirable to conduct accelerated fatigue tests on developmental prototype FRP structures to define weak points and check suitability in service. Although the load or deformation system used may be a reasonable facsimile—in kind—of that encountered in service, it is usually exaggerated in magnitude to produce failure within a reasonable time. A difficulty then arises on extrapolation of test life to service life. A rational procedure is outlined whereby this may be done, on basis of strains measured in the structures, cycles of load to failure, and a basic fatigue curve for the material.

4-3. Glass Reinforced Plastic Aviation Gas Turbine Compressor Housing

C. H. Vondracek and R. N. Sampson, *Westinghouse Electric Corp.*

This paper describes an application using phenolic and polyester resins, reinforced with glass fiber. Engine tests showed that the plastic housing performed as well as the magnesium ones. With the recent improvement of high temperature resins and improved techniques of applying resins to the glass fibers, more applications of plastics to aircraft engines can be expected. The biggest problem has been overcome—that of proving that a high temperature structural plastic molding can be successfully adapted to aircraft engines.

4-4. Nature's and Man's Approach to Filament Reinforcement

Curt A. Knoppel, *Proman, Inc.*

How slender branches of growing trees carry rich loads in violent storms is an everyday phenomena. Some years ago our interest was aroused and an entirely new field for exploration was opened. It was felt that the study of natural fiber arrangements could lead to new understanding of filament reinforcement in plastics applications. Bamboo is an exciting example of Nature's superior engineering with continuous filaments and a "plastic" binder. Body tissues, muscles, tendons, etc., show strength and endurance, are functional and, again, show the logic in materials handling by the Master of Creation. In an exploratory project by Proman, Incorporated a common branch from a growing tree has been used in studying filament orientation and architecture with the aim of learning to apply this information in reinforced plastics engineering.

Tuesday Noon, January 24, 1961

Education Luncheon

Chairman, C. C. Winding,
Chairman, SPE Education Committee

Brief remarks—George W. Martin, *SPE President*

Principal speaker—**Dr. E. W. Comings,**
Dean of Engineering, University of Delaware

Blue Room **Tickets $4.50**
available at registration desk

Tuesday Afternoon—January 24, 1961
1:30 to 3:10 P.M.

Session 5—Crosslinking of Polymers

MODERATOR, **Paul E. Willard,** *Food Machinery and Chemical Corp.*
Location: Main Ballroom

5-1. The Promotion and Retardation of Cross-Linking in Thermally Processed Polyvinyl Chloride Systems

C. H. Fuchsman, *Ferro Chemical*

Cross-linking of polyvinyl chloride in plasticized and unplasticized systems is described as a function of several processing variables, with particular emphasis on the types and concentrations of stabilizers present. Cross-linking is measured as swelling in tetrahydrofuran or cyclohexanone solvent. Metal salts of carboxylic acids (e.g., Ba, Cd, Zn, Pb, Ca salts of fatty acids), and phosphites (e.g., triphenyl phosphite, tri 2-ethylhexyl phosphite), generally tend to promote cross-linking, at least in the earlier stages of thermal processing of vinyls. Some compounds containing epoxy groups retard cross-linking, while others have little effect. The variable performance of phenolic compounds is discussed with a view to defining the structural elements which affect cross-linking.

5-2. New Crosslinkers for Furfuryl Alcohol Resins

Erik R. Nielsen, *Armour Research Foundation*

Thermoset furfuryl alcohol resins are well known for their resistance to non-oxidizing acids, alkalies, and solvents. They have found extensive use as corrosion-resistant cements. There are several reasons why this is the only large scale application of furfuryl alcohol resins: Up to now, the thermoset resin has been produced by the action of a strong acid (and heat) upon a liquid resin intermediate. The necessity of using a strong acid introduces a corrosion problem, and the resulting thermoset resin is very brittle and practically non-adherent to metals. The acid catalyses further build-up of resin chains and also promotes sission of the furan ring to a considerable extent. Crosslinking takes place at points of ring sission, with the result that a 3-dimensional network is formed. The crosslinker is the formaldehyde which is formed as a byproduct in the resinification process, and the short crosslinks are responsible for the brittleness and non-adherence of the conventional thermoset furfuryl alcohol resins. In the absence of a strong acid, the crosslinking rate of formaldehyde becomes very slow, even when heat is applied, and the crosslinked resin eventually formed is still brittle and non-adherent.

5-3. Chemically Cross-Linked Polyethylene

B. C. Carlson, *R. T. Vanderbilt Co., Inc.*

Thermoplastic polyethylene may be cross-linked by certain organic peroxides through a free radical mechanism. A few peroxides for cross-linking low and high density resins are discussed. Compounding of cross-linked polyethylene, including the use of carbon black and inorganic fillers, and antioxidants are reviewed. Interest is high for use in pipe, hose, sponge, and molded articles.

Tuesday Afternoon—January 24, 1961
1:30 to 3:10 P.M.

Session 6—Extrusion Panel

MODERATOR, **Frank Nissel,** *Prodex Corp.*
Location: Terrace Banquet Room

Topics: Extrusion equipment
Extrusion resins and compounds
Extrusion processes and techniques

Tuesday Afternoon—January 24, 1961
1:30 to 3:10 P.M.

Session 7—Reinforced Plastics (II)

MODERATOR, George Epstein, *Aerojet-General Corp.*
Location: West Ballroom

7-1. High Temperature Resin Developments For Filament Winding

J. V. Kindall and S. E. Susman, *Narmco Industries, Inc.*

Recent studies under Wright Air Development Division sponsorship to develop an improved high temperature resin for glass filament winding have been highly successful. The results of an extensive resin screening and test evaluation studies were used as the basis for subsequent resin modifications and resin synthesis. A wide variety of high temperature resin systems were evaluated including epoxies, epoxy novolacs, phenolics, silicone phenolics, and silicones. Vinyl substituted epoxy resins were synthesized and evaluated for improved heat distortion properties. The Naval Ordnance Laboratory developed filament wound ring specimen was used extensively for resin evaluation. Excellent tensile stress correlation between filament wound rings and glass strands was obtained at all temperatures up to 750°F for the better resin systems.

7-2. A Study of Maleate and Fumarate Polyester Resins

R. E. Park, Ruth M. Johnston, A. D. Jesensky, R. D. Cather, *Pittsburgh Plate Glass Co.*

A comparison of polyester resins made with maleic anhydride and fumaric acid was made. A systematic series of mixtures of maleates and fumarates were evaluated in terms of gel tests and physical properties. The analytical method used was a differential infrared technique. The changes noted in the properties of the resins were correlated with the relative ratios of the two forms. The first type of resin chosen for this study was a typical polyester used in a molding resin. The polyesters were made from propylene glycol, maleic anhydride or fumaric acid and phthalic anhydride. The maleate and phthalate were present in equimolar amount. Resins containing high percentages of maleate (compared to fumarate) had lower heat distortions and longer gel and cure times. These differences were most obvious in room temperature cure systems. A second resin, with much lower reactivity, was used to confirm the evidence obtained by the above method. The differences in properties of maleates and fumarates were more pronounced with less unsaturation in the resin.

7-3. The Effect of Finishes on Heat Resistant Phenolic and Modified Epoxy Laminate Systems

John Miglarese, *Micarta Div., Westinghouse Electric Corp.*

This investigation deals with the influence of finishing agents on glass fabrics when converted into resin laminate systems. The physical and electrical properties of postcured phenolic and epoxy laminates are described. Findings substantiate that the finish is paramount especially in the phenolic system, but this was not so pronounced on the epoxy laminates. The study of finishes to achieve more useful characteristics are being pursued in Westinghouse's laboratories.

Tuesday Night—January 24, 1961
8:00 P.M.

Session 8—Thermoplastics

MODERATOR, Hiram McCann, *Modern Plastics*
Location: Terrace Banquet Room

8-1. Plasticizers from Synthetic (ALFOL) Fatty Alcohols

B. W. Terry and W. L. Groves, *Continental Oil Co.*

Plasticizers made from normal alcohols have been on the market for several years. These plasticizers have been well received where low volatility, low temperature flexibility and excellent water extraction properties are of major importance. The alcohols used in making these plasticizers were derived from natural fats and oils. It is now possible to make these alcohols from petroleum raw materials. The synthetic alcohols are presented as versatile raw material for the production of plasticizers.

8-2. Paste Extrusion of Filled Compositions of "Teflon" 6 TFE-Fluorocarbon Resin for Wire Insulations

R. W. Johnson, *E. I. du Pont de Nemours & Co., Inc.*

The abrasion resistance of insulations of paste extruded "Teflon" 6 resin is improved 10 to 150 percent by blending fillers with the resin prior to lubrication and extrusion. By using special constructions, the addition of filler has little or no effect on the electrical properties of the insulation. In EE-type constructions (15-mil wall thickness), the room temperature cut-through resistance of insulations was improved 30 to 50 percent by the addition of fillers. The high temperature cut-through was much better with the filled insulations than with the insulations of pure "Teflon" resin. The upper limit of filler concentration for good extrusion performance was 2.5 to 10 percent, depending on the wire construction and type of filler used. The materials used for fillers are: Asbestos, calcium silicate, graphite, talc, quartz, glass fibers, finely divided silica, and fibrous magnesium silicate.

8-3. Processing Characteristics and Applications of Estane Thermoplastic Polyurethanes

C. A. Waugaman, *B. F. Goodrich Co.*

A family of thermoplastic polyurethanes has been introduced which may be processed by the standard thermoplastic processing methods of extrusion, injection molding, compression molding, calendering, and solution techniques. The products manufactured from Estanes have properties comparable with polyurethanes which require a hydroxyl-isocyanate cross-linking or curing operation. Processing conditions similar to those used with polyvinyl chloride will develop the high tensile strength, good tear strength, ozone, solvent, and abrasion resistant properties which are characteristic of this unusual family of polymers. Present applications include wire and cable jacketing, fuel hose, small hose tubing, belting, pump components, sheeting for equipment liners, gloves, shoe heel lifts, and coatings.

8-4. Extra High Impact Polystyrene

J. C. Misko and J. A. Edler, *Union Carbide Plastics Co.*

Extra high impact polystyrenes have been available for many years. However, the introduction of new formulations has increased their popularity greatly during the past year. The extra high impact polystyrenes now represent one of the best bargains in impact strength in plastics today. (A comparison with other materials will be shown.) The main advantage of the extra high impact polystyrenes are toughness and good elongation. (Examples of the room and low temperature properties will be demonstrated.) Because of these properties the materials are being injection molded into appliance parts, television cabinets, etc. The compounds are also being used to upgrade the strength of medium impact or high impact polystyrene where these particular compounds are not sufficiently tough. This is done by either direct compounding or by preblending the components and injection molding them through breaker plates.

8-5. Properties of a New Polyester Film

M. T. Watson, *Tennessee Eastman Co.*

The condensation polymer of 1,4-cyclohexanedimethanol and terephthalic acid, from which Kodel polyester fiber is made, can be readily melt-extruded as clear film. By quenching, the extruded film can be produced in the amorphous state, after which it can be oriented by stretching in the lengthwise and widthwise directions. This orientation results in enhanced physical properties, and by suitable heat treatment the film can be crystallized to confer excellent dimensional stability. The purpose of this paper is to discuss properties of such films. Representative physical properties of cross-stretched and crystallized films of poly(1,4-cyclohexylenedimethylene terephthalate) are compared with those of poly(ethylene terephthalate).

8-6. Self-Extinguishing Polystyrenes

J. C. Misko and C. F. Martino, *Union Carbide Plastics Co.*

Polystyrene compounds have been developed, ranging in notched Izod impact strength from 0.35 to 1.2 foot pounds per inch of notch. In sections 0.015 inch or over as tested by ASTM method 635-56T these materials are self-extinguishing whereas standard polystyrenes have a burning rate ranging from 0.60 to 1 inch per minute. This opens to polystyrene numerous applications in which flame retardance is a requirement. The lowest impact type resembles general purpose polystyrene in physical properties. It is similar in tensile strength, flexural strength, rigidity, elongation and ASTM heat distortion temperature. A comparison will be shown. The highest impact type is slightly tougher than a standard high impact polystyrene and slightly lower in tensile and flexural strengths and rigidity. It is similar in heat distortion temperature. A third formulation is also available with a notched Izod impact strength of 0.7. This formulation compromises the properties of the two extremes. A chart illustrating the relation will be shown.

8-7. (Part 1) Polyvinylidene Fluoride—RC 2525 Resin Properties

W. S. Barnhart, R. A. Ferren, and H. Iserson, *Pennsalt Chemicals Corp.*

A new fluorine-containing thermoplastic polymer of polyvinylidene fluoride is described. The resin has an excellent balance of mechanical, chemical, and thermal properties. These properties are detailed in the paper.

8-7. (Part 2) Polyvinylidene Fluoride Resin, Fabrication and Application

N. Capron, A. A. Dukert, M. E. Melville, and L. E. Robb, *Acme Plastics Products Co.*

Article covers a broad area of subjects dealing with general forming and use of a new resin. Included: Transfer molding, pigmentation, machining, welding and heat sealing, extrusion, and compression molding.

Tuesday Night—January 24, 1961
8:00 P.M.

Session 9—Thermosets

MODERATOR, **Malcolm W. Riley**, *Materials in Design Engineering*
Location: Main Ballroom

9-1. Fabrication of High Temperature Molds and Dies Using Epoxy Resin Systems

Thomas Schaub, *Furane Plastics, Inc.*

This paper discusses the fabrication of two types of molds and dies utilizing new epoxy resins and hardeners as well as the various filler reinforcements. One method uses the hard gel coat backed up with laminating resin reinforced with glass cloth. The second method involves the use of a hard surface gel coat followed by aluminum needles ("Epocore F") and a high temperature epoxy resin binder, cast without pressure or special equipment. Comparative results are given on the heat transfer properties of the Epoxy-Glass system as well as the Epoxy-Aluminum system to steel, aluminum and plastic. Test results are described on the compressive strength of the Epoxy systems at room temperatures as well as elevated temperatures to 300°F.

9-2. New Techniques in Applying Epoxy Troweling Compounds

T. S. Loeser, *Union Carbide Plastics Co.*

The art of applying epoxy troweling compounds has been advanced by the development of several new techniques involving both equipment and resin hardener chemistry. The equipment responsible for this includes an epoxy troweling compound mixer developed by UCPC and a device for spraying highly filled epoxy formulations, manufactured by the Quickspray Company. The resin hardener chemistry mentioned simply includes the use of latent type hardener as applied to epoxy troweling compounds. Epoxy troweling compounds, now generally appearing as two package highly formulated systems soon may become obsolete. The newest epoxy troweling systems will consist of three simple components—resin, hardener and fillers. The most obvious advantage is the greatly reduced cost for compounding but the underlying advantage is the ease with which these three components can be handled in the epoxy troweling compound mixer.

9-3. Dimensional Stability Improvement of Melamine Impact Molding Compounds

W. A. Laurie, *Melamine Plastics Corp.*

Melamine molding compounds reinforced with both cellulosic and mineral, glass fibers, have continually given difficulties with respect to dimensional stability and warpage. Recent efforts directed at overcoming the problems of dimensional instability have been measurably successful. The problems in both cellulosic and glass reinforced materials appear to be primarily associated with: 1. The control of volatiles; 2. The bonding of resin and filler; and 3. Uniform cure.

A program, initiated to improve the dimensional stability and warpage resistance of a 1.0 ft.-lb. impact grade cellulosic melamine compound, was undertaken. The effects of the three aforementioned variables were studied.

9-4. New Heat-Resistant Phenolic Molding Materials

W. G. Colclough, J. Harding, and C. Y. Meyers, *Union Carbide Plastics Co.*

A new phenolic molding material with good heat resistance has been developed. It is estimated that the material can be used at operating temperatures 75°F higher than are used for commercially available asbestos-filled phenolics. Applications: Missiles and high-speed aircraft; old applications which are being redesigned. For example, in miniaturized components having higher operating temperatures than conventional electronic units; and replacement of ceramic and metal parts for economic reasons or other advantages such as lightweight.

9-5. High-Strength Laminating Varnishes for Paper-Base Phenolic Tubing

T. G. Crawford, *Micarta Div., Westinghouse Corp.*

Article contains a description of a relatively inexpensive paper-based, phenol formaldehyde tube with specific high strength properties. One of the requirements of manufacturers of drawn synthetic yarns in bobbins made from such tubing is a higher flexural modulus together

with high impact strength. In developing such a tubing, some other physical properties were improved markedly.

Wednesday Morning—January 25, 1961
9:00 to 11:15 A.M.

Session 10—Polymer Properties (I)

MODERATOR, **Herman S. Kaufman,** *Allied Chemical Corp.*
Location: Terrace Banquet Room

10-1. The Different States of Polymers Based on Their Thermomechanical Properties

M. Chatain and P. Dubois, *Centre d'Etude des Matieres Plastiques, 21, rue Pinel, Paris 13°*

The effects of associated mechanical and thermal stresses on transition temperatures characteristic of changes of state in polymers are examined. Relationships are demonstrated between basic molecular structure of polymers and the possible existence of three different states, namely, rigid, plastoelastic, and rubbery. These characteristics are of basic significance in the selection of polymers for thermomechanical applications.

10-2. Measurement of Orientation in Polystyrene Film and Sheet

C. T. Hathaway, *Monsanto Chemical Co.*

Orientation is the key to useful polystyrene film and sheet. If unoriented, polystyrene sheet shatters on bending. If improperly oriented, it cracks or tears so readily as to be useless. Therefore, a technique for measuring orientation is essential to any study of this material. Birefringence, tensile strength, elongation during processing, shrinking on re-heating, and orientation release stress (OS) as determined by ASTM D-1504 are discussed as possible measures of orientation. The Bailey Stress Unmolding Tester, on which ASTM D-1504 is based, is described and reasons for considering modification of both apparatus and procedure are presented. A new apparatus is described using a Statham G1-80 load cell and electronic indicating system (LR1-2) rather than the Bailey lever arm system.

10-3. An Analysis of Density Data from Annealed Polypropylene Film

Edward D. Henze and Frank Sliemers, *Kordite Co*

A large amount of information has been published which describes the physical changes taking place when a molten polymer is suddenly cooled to a temperature below its crystalline melting point. The subsequent increase in crystallinity and density have been carefully analyzed for many polymers, including polypropylene. However, it is often observed that, as the crystallinity approaches completion, the data deviate significantly from the relationships developed for these systems. Also, it is not possible to use the existing relationships for changes in films whose thermal history is not completely known; with a degree of crystallization over fifty per cent and with nucleation very nearly complete.

10-4. Thermodynamic Diagrams for Polyethylene Resins

J. M. Lupton, *E. I. du Pont de Nemours & Co., Inc.*

For resins of room temperature density 0.91 to 0.96 g/cc, enthalpy and internal energy diagrams have been developed from 0 to 200°C and up to 1000 atmospheres. These diagrams can be used for estimating properties for which data are not available, and provide unified view of many properties of polyethylene under conditions of fabrication and use. Extent of crystallinity estimates can be made from enthalpy, internal energy, specific volume, compressibility and melting point data provided for hypothetical amorphous, crystalline and actual resins.

Wednesday Morning—January 25, 1961
9:00 to 11:15 A.M.

Session 11—Injection Molding (I)

MODERATOR, **Jerome L. Formo,** *Minneapolis Honeywell Regulator Co.*
Location: Main Ballroom

11-1. Effects of Basic Polymer Properties on Injection Molding Behavior

R. B. Staub, *Union Carbide Plastics Co.*

The injection molding behavior of polymers is determined by their thermal properties and flow properties. Thermal properties include specific heat, thermal conductivity, thermal diffusivity, coefficient of thermal expansion, crystallinity at normal temperatures, and transition temperature. Flow properties include Newtonian or non-Newtonian behavior during flow, and viscosity, which is related to the polymer structure. Data on styrene resins, vinyls, polycarbonates, and polyolefins are used to illustrate the dependence of injection molding behavior on thermal and flow properties.

11-2. Injection Molding Machines 1961

W G. Kriner, *Plastics Machinery Division, Hydraulic Press Manufacturing Co.*

The expanding market for injection molded plastic parts in automotive, housewares, appliance and electrical applications is introducing new production speed and quality standards for much of the plastic industry. These higher standards are causing many molders concern because the older standard injection machines will not meet demands. With these production problems and increasing price competition most molders will be studying new equipment in 1961.

Accordingly, more than ever, there is a need for every molder to be well informed when selecting machinery. This review is presented to familiarize the molder with the design concepts of the various injection ends while identifying their apparent advantages and disadvantages.

11-3. Comparison Between Plunger and Screw Injection Units

Richard Maier and Andre Thierstein, *Buhler Brothers, Uzwil, Switzerland*

Shot volume, pressure transfer and homogeneity of melt the reciprocating screw machine is superior to the conventional plunger machine. Compared with the preplasticizing systems with plungers or screw the superiority of the reciprocating screw machine lies mainly in a better homogeneity of the melt produced. This difference enables the machine to open injection molding to new prospects, in extending the process to high quality constructional parts as well as making it practicable for new materials or such materials which in the conventional manner of injection molding were beyond its access.

11-4. Molding High-Density Polyethylene in Large Boxes, Trays and Lids

J. V. Smith, C. G. Williams and L. R. Alexander, *Phillips Chemical Co.*

This paper presents some general procedures which will assist in producing relatively flat items and straight side deep draw boxes. Problems that arise and the solutions for them also are discussed. High density olefin resins are highly crystalline materials. The rate of cooling of the plasticized material will affect the resulting density, degree of crystallinity and shrinkage throughout the part. In order to mold a relatively flat section, control must be maintained of these variables which can be used to an advantage and will be the means by which warpage in a part is reduced or eliminated. Throughout

this presentation emphasis will be placed on the need to have uniform wall thickness, symmetry of design in the part and uniform polymer flow throughout the part. The location of water channels or means of cooling should be symmetrical with the part design and flow pattern wherever possible.

Wednesday Morning—January 25, 1961
9:00 to 11:15 A.M.

Session 12—Statistics Panel

MODERATOR, L. M. Debing, *Monsanto Chemical Co.*
Location: Park Room

Panel Discussion

Topic	*Panel Member*
Design of Experiments	Dr. W. J. Youden, *National Bureau of Standards*
Control of Manufactured Quality Control Charts for Attributes	Dr. A. J. Duncan, *Johns Hopkins University*
Sampling Plans	Dr. W. R. Pabst, Jr., *Bureau of Naval Weapons, Navy Dept.*
Use of Frequency Distributions in Setting Specifications	Francis J. Cullen, *National Plastics Products Co.*

Wednesday Morning—January 25, 1961
9:00 to 11:15 A.M.

Session 13—General Session (I)

MODERATOR, Ernest Moslo, *Moslo Machinery Co., Inc.*
Location: West Ballroom

13-1. Toxicology of Aliphatic Amine Curing Agents in Epoxy Tooling Systems

H. L. Thomas and J. W. Guyer, *Ren Plastics, Inc.*

For many years, room temperature-curing epoxy resins have been the principal resinous materials used in plastics tooling. Many toxic reactions of workers in the field could be traced to contact with the aliphatic amine curing agents, especially diethylenetriamine and triethylenetetramine. The most satisfactory solution to the toxicity problem involves condensation of the polyamine with a liquid epoxy compound. Such hydroxyalkylated products generally balance low vapor pressure with relatively low viscosity, good compatibility with epoxy resins, and increased reaction rates. In all tests on animals, these materials showed lowered toxicity, when compared to unmodified polyamines. In tests on humans, various degrees of irritancy were observed.

13-2. Hydraulic Fluids, Fact and Fancy

George R. Arbocus, *E. F. Houghton & Co.*

A review of terminology of hydraulic oils is covered in this article. Also contained is a chart describing a test program which was an attempt to find a combination of time, temperature, and catalysts which could prove out one oil over others. The article also contains a bibliography of publications dealing with hydraulics.

13-3. Controlling Quality in A Plastics Processing Plant

Walter C. Siff, *The General Tire & Rubber Company*

A comprehensive program is described for substantially reducing quality losses and increasing customer satisfaction in a plastics processing operation. Examples are given based upon actual experience in two vinyl processing plants. The need for effective controls is discussed and the areas of operation requiring control are developed. These include specifications, introducing new or modified products into the operation, procuring raw materials, manufacturing and disposing of finished products—insofar as these activities bear on the level of quality loss. A comprehensive program including all of these activities must be interrelated with all the activities of the enterprise. For this reason, the role of the sales, purchasing, manufacturing, engineering, product development, and accounting functions in the improvement of quality is examined.

13-4. Plastics Used in Electrical Appliances

Louis M. Kline, *Underwriters' Laboratories, Inc.*

The designers of electrical appliances have now been provided with plastic materials to replace metal, glass, wood, ceramic, and other materials. Their quick and overwhelming response, although mutually desirable, also brings questions and problems. Some of these are: (1) what inherent characteristics of plastics must be considered in selecting a plastic, (2) how can the proper plastic be selected early in the design stage, (3) what specific considerations must be weighed where fire, shock and accident hazards exist, and (4) is there a guidance source of safety information related to plastics used in appliances. It is the purpose of this paper to expand on the safety problems of selecting plastics for use in electrical appliances and to outline the approach and current progress of the MCA-sponsored research being conducted by Underwriters' Laboratories, Inc.

Wednesday Noon, January 25, 1961

Membership Luncheon

featuring
Presentation of 1960 Annual Report
Introduction of SPE 1961 Officers
Annual Business Meeting of the Society

President George W. Martin presiding

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Wednesday Afternoon—January 25, 1961
1:30 to 3:10 P.M.

Session 14—Heat Stable Polymers

MODERATOR, B. G. Achhammer, *National Bureau of Standards*
Location: Terrace Banquet Room

14-1. Research and Development of High Temperature Stable Polymers

H. H. Levine, *Narmco Industries, Inc.*

This paper describes research aimed at achieving structural adhesives and laminating resins useful at 1000°F for up to one hour. For such environmental conditions, semi-inorganic polymers could provide the necessary resistance to temperature and/or oxidation. It is the goal of this work to achieve semi-inorganic polymers of useful, high molecular weight by using high molecular weight, heat stable organic polymers and causing them to react with inorganic reagents. To evaluate the present state of the art, the best heat resistant, commercially available resins were used as adhesives and laminating resins under the above test conditions. With the exception of epoxy and epoxy containing systems, the organic adhesives and laminating resins performed surprisingly well. After one hour at 1000°F the best tensile shear value was 650 psi while the best flexural 49,000 psi was obtained on a parallel wound flat laminate under the same conditions. It seems that epoxy resins as they are known today should not be considered for 1000°F use.

14-2. **Inorganic-Organic High Polymers, Phenoxyaldehyde Resins of Titanium (IV), Zirconium (IV), and Hafnium (IV)**

R. J. Landry and E. H. Bartel, U.S. Naval Ordnance Test Station

A new series of inorganic-organic high polymers have been synthesized namely; the metaloxene polymers of phenolaldehyde. Titanium (IV), Zirconium (IV) and Hafnium (IV) phenolaldehyde have been prepared and other metals especially the refractory type metals may merit further development as calorobic plastic materials. The hafnium resin has been compression molded into a rocket-nozzle insert shape with satisfactory rocket-firing results.

14-3. **Heat Resistance and Molecular Structure**

Elwood Strebel, Cincinnati Test Laboratory

This work reviews the relationship of molecular structure to heat resistance in polymers. The various definitions of heat resistance are clarified by examining the methods commonly employed in the evaluation of this property. It is the investigation of phenomena occurring in these tests which may lead to improved understanding of the previously mentioned relationship. Such investigations can be pursued most diligently only in the light of knowledge regarding the strength and stability of chemical bonds. First considered is the correlation of bond dissociation energies of simple molecules with those of certain polymers. Carbon bonds here receive the greatest attention. Silicones and other organic polymers are viewed as contaminated quartz and diamond structures respectively.

Wednesday Afternoon—January 25, 1961
1:30 to 3:10 P.M.

Session 15—Injection Molding (II)

MODERATOR, Roger Staub, Union Carbide Plastics Co.
Location: Main Ballroom

15-1. **Comparison of Spiral Cavity Mold Flow with Laboratory Scale Flow Tests on Thermoplastics**

J. J. Gouza and G. G. Freygang, Rohm & Haas Company

Spiral cavity molds have been used for studying the flow of thermoplastics during injection molding. Such tests essentially duplicate production molding conditions and can be considered a good reference for evaluating other test methods. Data obtained from laboratory scale tests, such as the ASTM D569-59 Flow Temperature Test, R & H Co. Extrusion Test, ASTM D1238-57T Extrusion Test, and Brabender Consistency Test on several thermoplastics, are correlated to spiral cavity flow measurements. These data indicate that the small scale tests give a satisfactory prediction of the plastic flow characteristics of chemically or structurally related plastics. However, for unrelated systems the comparison is not satisfactory.

15-2. **Hydraulics on Plastic Injection Molding Machines**

R. H. Mezger, Vickers, Inc.

This article covers hydraulic system of injection molding machines. The two-pump pressure, low pressure unloading type system is most commonly used to provide the large volume of low pressure, and small volume of high pressure oil required. Also discussed is maintenance, including cleaning, regulation of oil temperature, and preventative maintenance.

15-3. **The Rotating Spreader—A Device for Superior Injection Molding**

Neil Keiser, L. H. Cirker, and P. D. Kohl, E. I. du Pont de Nemours & Co., Inc.

A mechanism was developed to rotate the spreader in injection molding machines. Operation of machines equipped with the rotating spreader disclosed major improvements in molding quality, production rates and color mixing. Molding pressures were lowered and changeover of materials facilitated. The design of a mechanically reliable, relatively inexpensive conversion of a 6-ounce machine is described.

Wednesday Afternoon—January 25, 1961
1:30 to 3:10 P.M.

Session 16—General Session (II)

MODERATOR, R. Kenneth Gossett, Gossett and Hill Co.
Location: West Ballroom

16-1. **Equipment and Tooling for Production With Epoxy Molding Compounds**

John L. Hull, Hull Corporation

Commercial availability of epoxy molding compounds has presented new opportunities to molders serving the electrical and electronic industries. Despite the fact that these new epoxy molding compounds are thermosetting, requiring both heat and pressure for polymerization, they do not behave exactly like the more familiar thermosetting compounds such as phenolics, ureas, melamines, alkyds, diallyl phthalates, etc. This paper discusses such differences in behavior, and shows how these differences have led to new designs in compression and transfer presses to enable easier production with epoxies. The paper also discusses cavity layouts, land areas, runner sizes, vents, knock-outs, and other tool design aspects requiring special attention for trouble-free epoxy molding.

16-2. **Foamed Plastic Particles—Versatile New Materials**

Miss Betty Lou Raskin, Johns Hopkins University

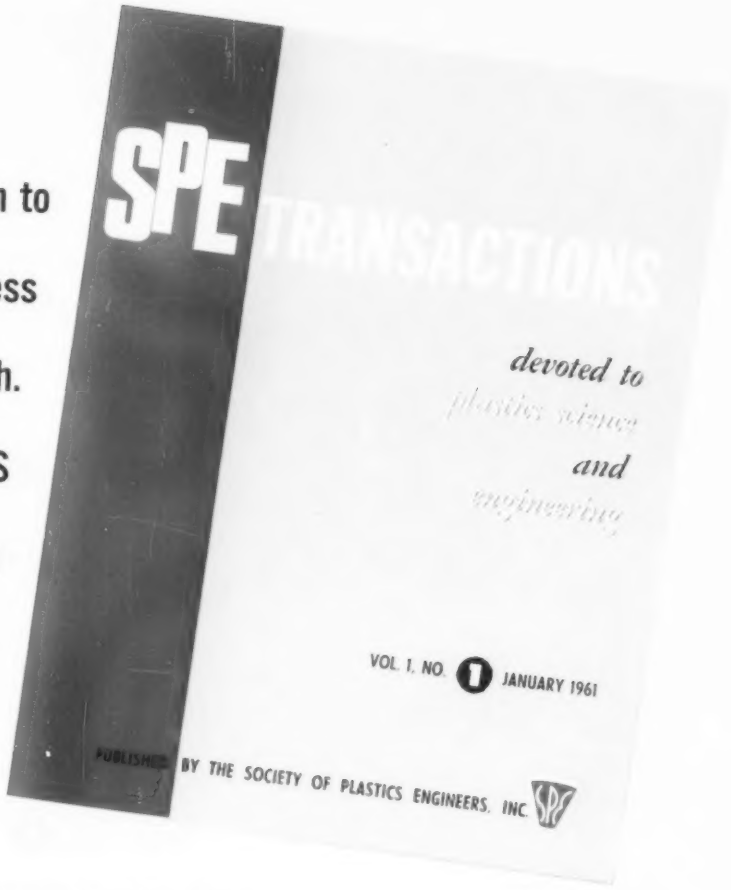
Foamed or expanded plastics are uniformly cellular or porous polymers which have a seemingly endless number of practical applications in virtually every conceivable field. Until recently these synthetics existed only in the form of bulk pieces of foam which had to be cut to fit specific applications, or foam in molded, shredded, extruded or bead form. This paper covers the author's invention of the newest form of foamed plastics—particulates. These particulates can be literally chemically-tailored to meet end-use requirements. When dispersed in air, tiny cellular plastic particles become constituent components of foamed plastic smokes, known as "flokes". These flokes give promise of opening broad new vistas not only for virtually all types of foamed plastics, but also for the smoke field in general.

16-3. **The Molded-In Hinge in Polypropylene Components**

Russell Hanna, Hercules Powder Co.

An entirely new concept in the design of hinges for plastic parts—the integral, molded-in hinge of unlimited flex-life—has been made possible by the balance of molding, stiffness, and flex-life properties unique to polypropylene. Prior to the advent of polypropylene, plastic materials and hinge designs were severely limited by poor fatigue resistance and/or the concept of a simple connecting strap acting as the hinge. Polypropylene hinges have withstood over one million flex cycles without failure, and design requirements for such hinges are so simple as to encourage the full play of the stylist's and engineer's ingenuity in part and mold design. The integral hinge can be used in conjunction with integrally molded catches, latches, or locks of comparable functionality and durability. Thus, it has become possible to design highly complex all-plastic assemblies requiring no accessory metal parts, lowering production costs and at the same time improving both the appearance and function of the product.

The solution to continuing progress is research. SPE TRANSACTIONS will endeavor to increase the tempo of progress by publishing the ever-increasing volume of literature devoted to polymer science and engineering of plastics. Over 700 polymer chemists and plastics engineers from all over the world have already subscribed. Why don't you? And see how basic research information can be your key to progress.



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Thursday Morning—January 26, 1961
9:00 to 11:15 A.M.

Session 17—Polymer Properties (II)

MODERATOR, **James F. Carley,** *University of Arizona*
Location: Main Ballroom

17-1. The Strength of Glassy Polymers

J. P. Berry, *General Electric Co.*

The Griffith theory for brittle fracture predicts that the tensile strength should be inversely proportional to the square root of the size of a defect or flaw in the sample tested. The validity of this relation has been investigated for the glassy polymers, poly(methyl methacrylate) and polystyrene. The results indicate that the strength of the polymers depends on two factors: (1) the surface energy, and (2) the inherent flaw size. The surface energy is primarily that dissipated in a viscous flow process and the inherent flaw size is related to the tendency of the polymer to craze under stress.

17-2. Time-Dependent Rupture of High-Impact Thermoplastics

J. V. Schmitz and R. S. Hagan, *General Electric Co.*

In structural applications, long-term properties are of great importance. There are substantial differences in time-dependent life of thermoplastic materials. These are not usually apparent from study of data commonly furnished by material suppliers. This paper discusses some aspects of the time-dependent behavior of rubber-reinforced thermoplastic materials that may be used in sheet thermoforming applications. The time-dependent properties studied include creep, creep-rupture, stress-relaxation, hysteresis and environmental stress-cracking. Processing effects were avoided through the use of compression molded or extruded samples of low molecular orientation.

17-3. The Environmental Stress Rupture of Poly-Ethylenes Used in Blown Bottle Applications

L. L. Lander, *Union Carbide Plastics Co.*

A new environmental stress cracking test based on a constant stress principle was described in the 1960 SPE Annual Technical Conference. Since that time, several polyethylenes have been tested by the environmental stress rupture test. This work has been directed toward determining the applicability of this test for evaluating and predicting the performance of polyethylenes for use in blown bottle applications. Data is presented which indicate that a direct correlation exists between the environmental stress rupture life of polyethylenes as determined by this test at 1400 psi and 40°C and the life of blown bottles as determined by simulated service life bottle crack tests. There is also a brief discussion on the effects of molding conditions and post-molded annealing conditions on the data obtained by the environmental stress rupture test.

17-4. Hardness of Polymeric Materials

Eric Baer, R. E. Maier and R. N. Peterson, *E. I. du Pont de Nemours and Co., Inc.*

A theory has been developed which describes the indentation and recovery of a spherical indenter in a plane slab of polymeric material. Equations are derived which relate hardness to the fundamental stress-strain properties of the material. When a large load is applied, the resistance to indentation has been shown to be controlled by the yield stress of the material. A material having a large yield stress will have a greater resistance to indentation than a material with a small yield stress. The instantaneous recovery which occurs when the load is removed from the penetrator has been described using the elastic analysis of Hertz. Relations have been derived which describe the recovery process in terms of the fundamental stress-strain behavior of the material.

Thursday Morning—January 26, 1961
9:00 to 11:15 A.M.

Session 18—Film and Sheeting Technology

MODERATOR, **Jules W. Lindau, III,** *Southern Plastics Co., Inc.*
Location: West Ballroom

18-1. Processing Variables and Their Effects on Properties of Coatings Made With Polyethylene, Polypropylene, and Nylon 6

John F. Morris, *Spencer Chemical Co.*

In order to learn more of the effect of processing variables on low density polyethylene and to determine what coated products could be made from polypropylene and nylon, a random balance experiment was designed to include the best possible resins in their groups and as many extrusion variables as could be handled conveniently. A widely used polyethylene resin having a melt index of 8 grams/10 minutes and a density of .916 grams/cc. was selected for this work. Since there are no nylon resins which are widely used for coatings, a commercially available nylon resin having a relative viscosity of 200 was used. An experimental polypropylene resin was available for this use. The processing variables which were incorporated in the experiment were screw speed, die gap opening, web speed, stock temperature, pressure drop across a head valve and position of the die over the chill roll nip.

18-2. The Effect of Extrusion Variables on the Fundamental Properties of Tubular Polythene Film

N. D. Huck and P. L. Clegg, *Imperial Chemical Industries, Ltd.*

The mechanism of formation of tubular polythene film is a complicated process, and extensive studies have shown that the properties of the film made are influenced profoundly and in a complex way both by the processing conditions used and by certain design features of the equipment. Studies of the effect of the extrusion variables on the more important film properies, both optical and mechanical, are reviewed in this paper. The results are discussed in terms of the fundamental nature of polythene film, its surface, its crystalline structure and its orientation. It is shown that the properties are determined almost completely by the melt history from just before the die to just after the freeze line. Die profile, melt drawing and cooling are therefore of prime importance in the control of the appearance and strength of the film produced.

18-3. A Comparison of Blown and Chill Cast Polyethylene Film

G. Denis Murphy, *Spencer Chemical Co.*

Film prepared from each particular technique will have peculiarities which are inherent to the technique as well as to the resin. Examination of film properties from several different polyethylene resins over the density spectrum shows these differences. Chill cast film is stronger having higher impact strength and better tear balance. Blown film strength is sensitive to blow-up ratio, haul off and drawdown which if out of balance will give rise to a tear tendency.

18-4. High Speed-Small Unit Polyethylene Overwrapping

Robert H. Cording, Jr., *Tennessee Eastman Co.*

Machines now on the market which overwrap articles in polyethylene film are relatively slow (around 60 items per minute) and wrap only larger articles such as paper

napkins, toilet paper rolls, etc. Development work is nearing completion on a machine which will overwrap items the size of cigarette packs, cough drop boxes, etc. in polyethylene film at speeds near 200 per minute. The paper gives details on advantages of polyethylene, sealing techniques, tear tape application, and solutions to film feeding problems.

Thursday Morning—January 26, 1961
9:00 to 11:15 A.M.

Session 19—Finishing (I)

MODERATOR, **Lee J. Zukor,** *Plastics Technology*
Location: Park Room

19-1. Design for Plastics Finishing

Fred Borries, *G. Felsenthal & Sons, Inc.*

Article covers basic ideas and methods for designing plastics for effective finishing. In designing for finishing, the designer should be concerned with the exact placing of paint breaks, color pads, recessing, and/or raising of letters and numbers.

19-2. Hot Stamping of High Luster Metallic Colors

Martin A. Olsen, *Olsenmark Corp.*

Plastic parts that are used in appliance, automotive parts and packaging must be generally decorated, trademarked or instruction and identifications applied. Hot leaf stamping high luster metallic colors are most decorative and make the parts much more saleable and appealing to the consumer. Vacuum plated or metallized imitation roll leaf comes in an assortment of colors, ranging from silver, gold, copper to the general colors such as red, blue, green, etc. (yellow is gold). The manufacture of vacuum metallized leaf is complex, costly and quality controls cause variations in the end product. The leaf must be thoroughly tested before use and each lot received must be tested and compared to a so-called standard.

19-3. Effect of Coating Properties Upon Sequence and Economy of Plastic Decorating

T. E. Hayden and John Scharnberg, *Bee Chemical Co.*

Specific methods—spray painting, silk screening, roller coating, vacuum metallizing, hot stamping, etc.—are all used to decorate plastics. Many parts are successfully decorated using only one of the methods mentioned, however, many parts require the use of one or more of the decorating methods and some parts require virtually all of the methods. The selection of the proper methods, and their sequence, to provide the most economical finishing operation is a study in itself and requires considerable thought. To obtain the optimum sequence of operations one must be thoroughly familiar with the limitations and advantages of finishing methods, the end use of the decorated item, the plastic being decorated, material handling considerations, and types of paints available. This paper delves into this problem more completely for both first and second surface plastic decorating special problems which may arise because of complexities of design of a molded plastic part. Dangers to be avoided are also discussed.

19-4. Design of Modern Vacuum Metallizing Equipment

Howard M. Farrow, *NRC Equipment Corp., Subsidiary of National Research Corp.*

The basic parameters used for the design of metallizing equipment and the relation of these parameters to the successful application of vacuum metallizing of plastics is discussed. Various design approaches are used by different manufacturers of vacuum metallizing equipment. Each design approach has its advantages, and these advantages are outlined for the purpose of assisting those people interested in the most efficient vacuum metallizing operation.

Thursday Morning—January 26, 1961
9:00 to 11:15 A.M.

Session 20—Vinyl Plastisols

MODERATOR, **Saul Gobstein,** *Ferro Chemical Co.*
Location: Terrace Banquet Room

20-1. The Mechanics and Testing of Plastisol Gelation and Fusion

J. A. Greenhoe, *Monsanto Chemical Co.*

A physical picture of the mechanism of the change in state of a vinyl plastisol during heating is proposed. Various methods of testing plastisol gelation and fusion are assessed in terms of these proposed mechanics and in terms of their usefulness in commercial applications of plastisols. A plastisol on heating follows a viscosity rise of a type represented by the formula of Roscoe,

$$\eta_r = \left(\frac{1}{1 - C}\right)^{2.5}$$

where viscosity rises with increasing volume concentration of particles in a suspension.

20-2. Plastisol Gelation—A New Instrument, A New Formulating Technique

W. H. Bauer, *Union Carbide Chemicals Co.*

For many plastisol applications changes in viscosity during the fusion cycle are an important consideration. In rotational casting, hot dip coating, slush molding or vinyl foam applications, changes in the formulation to obtain desirable physical or economic properties can alter the temperature-viscosity characteristics of a plastisol to such a degree that the resultant vinyl article has imperfections which make it of little or no commercial value. From the examination of existing methods for the determination of gel rate curves, it was felt that these methods did not sufficiently approach the time cycles (heating rates) or were not representative of the shear rates normally encountered in end use. In addition, curves obtained over abnormally long time intervals were too closely grouped to define significant differences in gelation characteristics inherent in the various plasticizers. A new testing apparatus was developed, therefore, in an effort to overcome the above objections.

20-3. Plastisol Distribution in Rotational Casting

L. A. McKenna, *Union Carbide Plastics Co.*

Rotational casting is a process by which a vinyl plastisol (dispersion of vinyl resin in plasticizer) is heated while being rotated in a closed mold about two axes transverse to each other. The rotation distributes the liquid plastisol on the inner face of the mold where it is gelled by heat. The item so formed is obtained upon subsequent cooling and opening of the mold. Rotational casting of plastisols is rapidly becoming a large volume market for vinyl resins and related chemicals. To grow even larger, the process must produce satisfactory industrial articles as well as the familiar dolls and toys now being rotocast. Manufacturing of industrial parts will likely place greater demands on obtaining a uniform wall thickness in the product than has heretofore been the case. Uniform distribution of the plastisol is, today, largely the product of skilled and trial-and-error experimentation.

20-4. **Vinyl Plastisols for Low Temperature Fusion**

J. C. Robinson, The Goodyear Tire & Rubber Co.

Vinyl dispersion resins are so named because they are processed by dispersing the resin in plasticizer to form a paste. This liquid plastisol is then converted to the solid state by application of heat.

As heat is applied to the plastisol, two significant changes take place. First, the viscosity of the plastisol begins to increase until a gelled or solid state is reached. This solidification occurs rather suddenly and in a temperature range known as the gel temperature. This gelled plastisol, though solid, has little physical strength and is easily crumbled. To obtain optimum physical properties, additional heat must be applied to bring the plastisol up to the fusion temperature. At this temperature solvation of the dispersed resin particles takes place and the plastisol becomes a homogeneous mass. This article also studies other factors which have definite effects on physical properties.

Thursday Afternoon—January 26, 1961
1:30 to 3:10 P.M.

Session 21—Stability of Polymers

MODERATOR, **Herman Mark,** *Brooklyn Polyetechnic Institute*
Location: Main Ballroom

21-1. **Electro-Thermal Analysis of Thermosetting Polymers**

R. W. Warfield, *U.S. Naval Ordnance Laboratory*

A new technique has been developed for investigating the thermal degradation of thermosetting polymers. This technique, which has been given the name Electro-Thermal Analysis (ETA), is based upon analyzing the changes which occur in the temperature dependence and magnitude of the electrical volume resistivity of a polymer during pyrolysis. This technique appears to be extremely sensitive to define the onset of degradation in highly crosslinked polymers.

Electro-Thermal Analysis is carried out using the Continuous Current Monitoring Device (CCMD). This device measures the electrical volume resistivity of a known volume of polymer as a function of temperature. In order to carry out an ETA study, a solid polymer is subjected to successive periods of heating for times of 16 hours, increasing the temperature by about 40°C at each step. The magnitude and temperature dependence of the resistivity is determined after each such step.

21-2. **The Effect of Physical Treatment on the Stability of Polyamides**

M. M. Epstein and C. W. Hamilton, *Battelle Memorial Institute*

Chemical reactions such as hydrolysis, crosslinking, and photo-initiated oxidation, have been identified as the cause of gross deterioration of nylon's mechanical properties. However, this article reports on work which shows that a wide variety of internal physical changes, roughly grouped as crystallization, can also cause extensive damage.

21-3. **Effect of Gamma Radiation on Chemical Structure of Plastics**

V. J. Krasnansky, M. S. Parker, and B. G. Achhammer, *National Bureau of Standards*

Twelve plastics representing various chemical structures were studied as part of a program to determine the utility of plastics as packaging materials in the high radiation presentation of food. The plastics were exposed to selected dosages of Cobalt-60 gamma radiation in vacuum and in air. Gas evolution and changes in infrared spectra as a result of irradiation were used to hypothesize the relative stability of these plastics to irradiation. On the basis of these criteria it was found that plastics containing conjugated ring systems, ionic linkages, and chlorine in side groups were the most stable.

Thursday Afternoon—January 26, 1961
1:30 to 3:10 P.M.

Session 22—Blow Molding

MODERATOR, **Jules Pinsky,** *Plax Corp.*
Location: Terrace Banquet Room

22-1. **Blow Molding Machinery Developments**

W. O. Bracken, *Hercules Powder Co.*

Summary of the latest blow molding machinery developments. Production rates of 48-50 thousand 22 oz containers per day of varied shapes are reported as commercial. Incorporation of an accumulator has become more widespread for producing larger and heavier extrudates either as tubes or sheet. Another new development reported is the use of adiabatic extruders.

22-2. **Trouble Shooting in Blow Molding**

H. S. Malby, A. N. Ciarlone, and C. M. Greene, *Celanese Plastics Company*

With the increased use of extrusion blow molding as a fabrication technique, there has arisen a need for the evaluation and solutions of visual defects in blow molded articles. This paper covers many of the problems that arise and recommendations for their solution in the blowing of both the polyolefins and the cellulosics.

22-3. **Future Uses of the Blow Molding Process**

R. L. Wechsler, *Union Carbide Plastics Corp.*

The current use of blow molding exploits only one advantage of the process, the ability to form hollow shapes in a single operation. As the process matures other advantages of the process will be recognized and exploited in the fabrication of non-hollow articles. Blow molding will allow the development of new plastic applications and will compete with vacuum forming and injection molding in many areas.

Thursday Afternoon—January 26, 1961
1:30 to 3:10 P.M.

Session 23—Finishing (II)

MODERATOR, **T. E. Hayden,** *Bee Chemical Co.*
Location: Park Room

23-1. **Automatic Spray Painting**

C. V. Scantlebury and H. P. Miskill, *Finish Engineering Co., Inc.*

Mechanization of painting is being used in an ever increasing number of applications. It offers the advantages of improved quality, consistent results, lower labor costs and high volume of production per square foot of floor space. In general the quality of work produced by automatic painting will be superior to hand painting. If the correct machine is chosen, achievement of high quality is a matter of proper set up. Keeping the quality at a high standard has many facets but basically it is putting the same ingredients to work all of the time. This paper elaborates on proper controls.

Panel Discussion

Members of Panel—John Scharnberg, Martin Olsen, Fred Borries, C. V. Scantlebury, Howard Farrow, Lee Zukor, Angelo Larero, Ronald Cleveringa.

Topics: Decorating Polyolefins, Autmoation for Finishing, and Overcoming Vacuum Metallizing Production Problems.

Thursday Night, January 26, 1961

Banquet

Sheraton-Park Hotel, Cotillion Room

cocktails (no host) —6:30—Foyer
Dinner —7:30
Entertainment —9:30

featuring

The Rogers—Dance Team
Prince Hara—Thief of Bagdad
Alan Black—HarmonicaVirtuoso
Earl William—Tenor and Broadway Star and Lillian Murphy, Soprano, Radio City Music Hall Star

Tickets $10.00
available at registration desk

Friday Morning—January 27, 1961
9:00 to 11:15 A.M.

Session 24—Weatherability

MODERATOR, John B. Howard, *Bell Telephone Laboratories*
Location: West Ballroom

24-1. The Outdoor Durability of Plasticized Poly(Vinyl Chloride)

J. R. Darby and P. R. Graham, *Monsanto Chemical Co.*

This work indicates that, in weathering of PVC, horizontal exposure, and not 45° inclination, is more critical. Small concentrations of 2-ethylhexyl di-phenyl phosphate imparts significant stabilization to PVC-DOP systems, particularly in thin films. For optimum weather resistance, plasticizer concentration should be about 35-45 phr and that concentrations on either side of this level will result in more rapid degradation.

24-2. Weathering of Epoxy Resin Systems

A. N. Cianciarulo and F. E. Pschorr, *Ciba Products Corp.*

Various unreinforced epoxy resin/hardener systems were placed upon a weathering rack (as specified in ASTM D 1435-58) in Kimberton, Pennsylvania.

After completion of the exposure cycles, 3 months and 12 months, the samples were tested for the following:

Flexural Properties—ASTM D 790-58T
Tensile Properties—ASTM D 638-58T
Hardness—Barcol Impressor, Type J
Dielectric Constant—ASTM D 150-54T
Dissipation Factor—ASTM D 150-54T

Exposure is continuing and these properties will again be determined after an additional exposure period of 3 years or longer, depending upon the results.

24-3. The Predominant Reaction of Some Fluorinated Polymers to Ionizing Radiation Under Various Environmental Conditions

Robert Timmerman, *Radiation Dynamics, Inc.,* and William Greyson, *Hi Temp Wires, Inc.*

The original investigations made on Teflon TFE in a field of ionizing radiation consistently showed a degradation of the molecule due to irradiation. Gases were formed and collected. Physical properties were obtained. Molecular weight determinations were made. All evidence led to the fact that polytetrafluoroethylene underwent primary chain scission in radiation field. Recently it has been found that Teflon when irradiated in a high vacuum will degrade only slightly whereas a corresponding dose of radiation in air causes severe degradation.

24-4. Status of Investigations for Improving the Weatherability of Linear Polyethylene and Copolymers

C. Gottfried and M. J. Dutzer, *Celanese Plastics Co.*

For optimum outdoor serviceability with respect to retention of elongation, tensile strength, and melt index properties of molded items, the following steps are necessary: High density resin having as low a melt index as possible; design which minimizes molding stresses and strains; UV absorbers; proper choice of pigments. For instance, pigments such as green, orange, peacock blue, monastral purple, red and black in high concentrations will prolong the outdoor weatherability.

Friday Morning—January 27, 1961
9:00 to 11:15 A.M.

Session 25—Rheology of Polymers

MODERATOR, Bryce Maxwell, *Princeton University*
Location: Main Ballroom

25-1. Polyethylene Flow Data From Melt Viscometer and Commercial Extruder Measurements

H. P. Schreiber, *Canadian Industries Ltd.*

It is shown that for a wide variety of high pressure polyethylenes, the shear rate-shear stress (flow) data characterizing the extrusion behaviour of the melts in a commercial extruder can be predicted with good accuracy and great speed from flow data obtained from a gas operated high shear viscometer. Therefore, such extruder performance characteristics of a polyethylene melt as extruder power consumption can be predicted rapidly and reasonably accurately from h.s.v. data. Comparisons of flow data obtained from the h.s.v. and a commercial extruder also indicate some effects of extruder screw action on the viscoelastic properties of the melt.

25-2. Measurement of the Flow of Molten Polymer Through Capillaries

A. P. Metzger, *Battelle Memorial Institute*

In the evaluation of polymers, the quantity of molten material flowing through a capillary is frequently used as an indication of molecular weight. This flow rate depends not only on the molecularstructure of the polymer but also the melt temperature, applied load, and capillary dimensions. Extrusion data have been obtained for a number of polyethylenes, both high and low density, using flat-entry dies with L/D ratios ranging from 3 to 30. These data illustrate the pronounced effect of die dimensions. The flow rates depend not only on the L/D ratio (same diameter and increasing length) but also vary for dies of the same L/D ratio (change both orifice diameter and length). Relationships based on flow data through a specific orifice or for a particular type of polymer can not be extrapolated reliably.

25-3. The Flow Properties of Some Commercial Thermoplastics End Corrections in Capillary Flow and Their Implications In Die Design and Polymer Processing

L. B. Ryder, *Celanese Corporation of America*

End correction-shear rate-temperature curves and apparent viscosity-shear rate-temperature curves are pre-

sented for a number of commercial thermoplastic polyolefins and cellulosics. An example is given of how to use these curves to design dies of low length-to-diameter ratios and to calculate the error resulting from the neglect of the end correction. A method is given, based on the end correction curves, which may be used to apply an approximate correction to flow curves for which no entrance corrections have been made. It is recommended that future presentations of melt rheology data consist of entrance corrected flow curves and end correction-shear rate-temperature curves. Finally, it is shown, by way of a bottle blow molding example, that end correction data can provide a valuable indication of the elastic processing behavior of polymer melts.

25-4. Effect of Static Pressure on Polymer Melt Viscosities

James F. Carley, *University of Arizona*

Evidence indicates that increasing static pressure at constant pressure drop reduce flow rates of plastic melts very significantly, of polystyrene more than of polyethylene, but the reduction is much smaller than the speed up of flow brought about by an equal increase in pressure drop. The relationship betewen flow and static pressure appears to fit best the exponential form given by the Eyring equation, but is also fitted well enough by a power-law function so that the rheologist cannot detect the static pressure effect with present single-piston flow-tube rheometers and methods. The effect is of minor importance commercially except when operating near the freezing range of the melt, at high pressures.

Friday Morning—January 27, 1961
9:00 to 11:15 A.M.

Session 26—Heat Resistant Plastics

MODERATOR, Lawrence Shenker, *General Electric Co.*
Location: Terrace Banquet Room

26-1. Utilization of Plastics in Seal Design for Extreme Environments

Frank W. Tipton and George E. Trepus, *Boeing Airplane Co.*

The occurrence of man-made vehicles being sent into space has added a number of environment-imposed requirements on system seal materials not previously encountered in conventional aircraft. These added requirements imposed on elastomeric and plastic materials have inspired a number of investigations into their resultant effects, both from fundamental and end-item viewpoints. Accordingly, Air Force Contract AF 33(616)-5722 "Design Data for O-Rings and Similar Elastic Seals" with the Boeing Airplane Company, includes investigations into the effects of high temperature, ionizing radiation and cryogenic temperatures on the efficiency of elastomeric seals. Probably the most frequently encountered environmental extreme, is that of high temperature. Therefore, considerable attention has been given to the behavior of seal configurations at elevated temperatures.

26-2. Rapid Heating Method for Testing Plastics and Adhesively Bonded Systems

M. S. Allison, A. C. Johnson, R. B. Stabler, *Lockheed Missile & Space Div.*

This article discusses radiant heating test equipment for material evaluation of structural laminates and adhesives. The equipment, instrumentation, test procedure and recording of test results is reviewed.

26-3. Developments in Heat Resistant—Structural Non-Woven Reinforced Plastics

D. V. Rosato, *Raytheon Co. (now with Telecomputing Corp.)*

This paper provides information on predicting mechanical properties of bonded fibrous structures based on engineering properties of fibers. Basic analysis of engineered fiber theory is reviewed based on data from various sources, which in turn provides a practical theoretical approach in producing high strength–heat resistant structural materials for industry.

26-4. Development of a Reliable Insulation for Solid Propellant Rocket Motors

S. P. Prosen, M. A. Kinna, and F. Robert Barnet, *U.S. Naval Ordnance Laboratory*

High-pressure plastics molding techniques have recently been used to prepare insulations for a large high performance solid propellant rocket motor and have met with a high degree of success. The molding compound selected for this work was a phenolic filled with graphite and carbon and reinforced with aluminum silicate fibers. In making the bulkhead moldings, the actual bulkhead was used as the cavity of the mold and the material was molded in place. The sidewall insulation was premolded in sections with lap joints, and these were then bonded into place. By this technique, a high performance, reliable insulation was provided for the rocket motor.

Friday Morning—January 27, 1961
9:00 to 11:15 A.M.

Session 27—General Session (III)

MODERATOR, Peter W. Simmons, *Dow Chemical Co.*
Location: Park Room

27-1. Comparison of Plastisol Extrusion Coating with Conventional Coating Methods

C. H. Brower, *Union Carbide Plastics Co.* and R. A. Nunn, *Waldron-Hartig Div., Midland-Ross Corp.*

Vinyl dispersions are normally applied to cloth and other substrates by roller or knife coating. A new method for applying these materials has been recently developed, involving plastisol extrusion lamination. This article discusses the new and old processes as a guide to where and how each should be considered.

27-2. Adhesive Bonding—A New Concept in Structural Adhesives

Frank J. Riel, *Narmco Industries, Inc.*

The current status of metal to metal and sandwich panels suitable for operation over the temperature range of -67°F to $+250^{\circ}$F is discussed, and the basic principles governing their operation described. The constitution and geometry of existing adhesives are described, and their relationship to the base materials used in formulating the finished adhesive explained. A new concept in the geometry and composition of structural adhesives is presented. This concept is based on the premise that a single, homogeneous substance, having the proper strength, elasticity, surface tension, flow, viscosity, and curing rate makes the best structural adhesive.

27-3. Effect of Molding Conditions on Shrinkage of Modified Polystyrene

R. G. Hochschild, *Koppers Co., Inc.*

Changes in mold temperature markedly influence both the amount and the rate of shrinkage. The bars become shorter and shorter when the mold temperature is

raised from 100°F. to 150°F. This temperature change also causes an increase in the rate of shrinkage, especially in the case of "A" material, whereas "B" specimens shrink at practically the same rate, regardless which mold temperature is used. The effects of varying portions of the molding cycle were checked. In one set of experiments, a short injection time and a long cooling time were used, while in another series, the injection time was increased and the cooling time was shortened. Interestingly enough, neither of these changes affected the rates or the amounts of shrinkage. Both materials shrank roughly the same amounts at the particular conditions chosen.

27-4. Data Presentation for Cushioning Materials

R. C. Dove and W. G. Soper, *University of New Mexico*

A problem of considerable interest to the engineer charged with designing cushions is the one in which the outer case of a two mass system obtains its total velocity change in a time which is much smaller than the time over which the cushioned inner mass is accelerated. For problems of this kind, referred to as impulse problems, it is desirable to have test data presented in such a way that for a given set of design conditions the best available material can be immediately selected. This paper suggests how, by grouping the test variables, data from impact tests can best be presented.

Standby Papers (Session 28)

These papers will be presented orally in the technical sessions if time permits

28-1. Moldability and End Use Properties of High Density Polyolefin Blow Molding Materials

H. D. Bassett, R. E. Christensen, N. M. Burns, *Union Carbide Plastics Co.*

Test methods and their suitability as barometers of machine and end-use performance of resins are discussed in conjunction with the reported work. Relation between bench and end use tests is presented. Flow index, shear sensitivity, and density of high density polyolefin materials affect moldability and end use properties to an important degree. Experiments have shown low flow index is desirable from stress crack resistance and toughness standpoints, high shear favors moldability, and density as affected by composition, exerts an important influence on stiffness/stress crack resistance relationship.

28-2. Fail-Safe Safety Circuit on Injection Molding Machines

J. D. Sherman, *Reed-Prentice Div., Package Machinery Co.*

The problems and solutions to providing safer operation of plastic injection molding machines are explained in this new approach to operating safety. A monitoring type system assures much better protection for injection molding machine operators.

28-3. The Effects of Temperature and Humidity on the Dielectric Properties of Plastics

Gim P. Fong and Ralph C. Pratt, *Raytheon Co.*

With the advent of the space age, guided missile programs and complex guidance equipment, the various dielectric properties of materials have become extremely important. It is in this area that plastics through their versatility excell. Plastics generally have low specific gravities and their dielectric properties are such as to satisfy many of the electronic problems now in existence, such as radomes, R. F. windows, polarized gratings, horn covers and other radar applications. This investigation was concerned with changes in dielectric constant and loss characteristics and will include data obtained by measurements of selected materials under various conditions of temperature and humidity.

28-4. A Compact Internally Operated Miniature Valve for Pressure Balanced Impact Molding

Milton Ross, *The Milton Ross Co.*

This new technique is a foolproof automated multicavity system with independent, internally activated automatic valves using a hot runner technique and adaptable for all thermoplastics. Each valve is about the size of a lipstick tube and is completely confined within the mold. It is operative on most injection molding machines. Its simplicity readily allows conversion of existing molds and reduces the concern of where to gate as the runner system can be brought in from almost anywhere in the mold.

28-5. Impact Testing of Extruded Thermoplastic Sheet

R. S. Hagan, J. V. Schmitz and D. A. Davis, *General Electric Co.*

There has been much question on the precise techniques that should be used to measure impact resistance. This paper surveys the various methods for testing impact resistance of extruded thermoplastic sheets. It gives comparative data for many of the current commercial high-impact polystyrenes, acrylonitrile modified polystyrenes, rigid vinyl and polyolefins.

Methods used for measuring impact resistance include conventional Izod, Charpy, Gardner and tensile-impact techniques as well as falling dart tests. Also included are high-speed tensile and flexural tests which indicate stress-strain behavior as well as total energy to rupture. Tests are compared over a temperature range of —30°F to 150°F. Correlations are noted among the various methods. Molecular orientation is also discussed.

28-6. Flame Resistant Epoxy Laminates

J. L. Welch, Jr., *Union Carbide Plastics Co.*

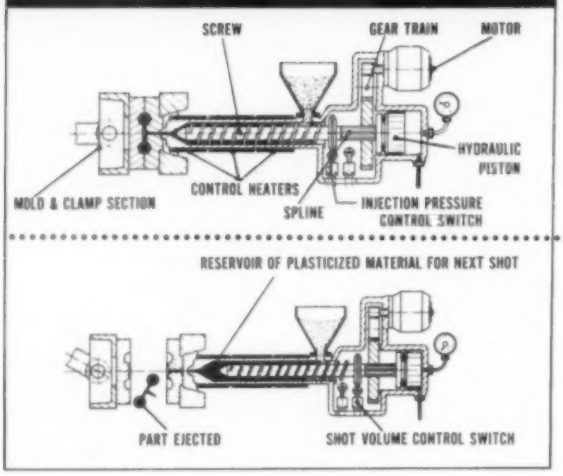
The increased interest in fire-resistant resins led to the preparation of a flame retardant epoxy resin. This material, largely the diglycidyl ether of tetrachlorobisphenol A, is a semi-crystalline resin. In casting and wet layup laminating, hot melt techniques are required, and in dry layup laminating, conventional methods are employed, but crystallization from solution in the treating operation must be avoided. The resin can be cured with conventional hardeners such as aromatic amines, anhydrides, and boron trifluoride complexes.

28-7. Vacuum Hopper and Fine Screens in the Extrusion of PVC Dry Blends

N. T. Flathers, R. E. Johnson, V. R. Pallas, W. M. Smith, *Escambia Chemical Corp.*

This paper fully describes the PVC resin characteristics and the blending and extrusion equipment and associated technology required to obtain high quality dry blend extrusions at high production rates. Clear and filled rigid and elastomeric PVC products and PVC wire insulation are features. Excellent quality PVC insulated wire has been produced at extrusion rates of 180 lbs./hr. on a 2-½" extruder equipped with a vacuum hopper and a 15 horsepower extruder drive. There was no porosity in the coating and the surface was smooth. Greater production was limited only by lack of power. Currently, a 30 horsepower motor drive is being used for still higher rates of extrusion. Elastomeric profile extrusions have also been studied at these high rates.

SCREW PLASTICIZING



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- molding pressures reduced; fewer molded-in strains
- mold shrinkage reduced; molding to closer tolerances
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- excellent color dispersions and rapid color changes
- optimum physical and chemical properties of polymer
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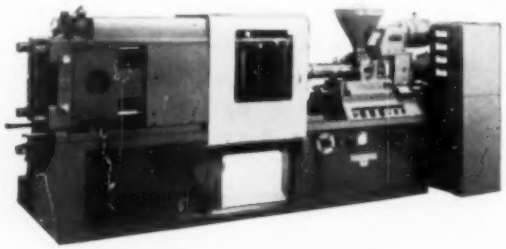

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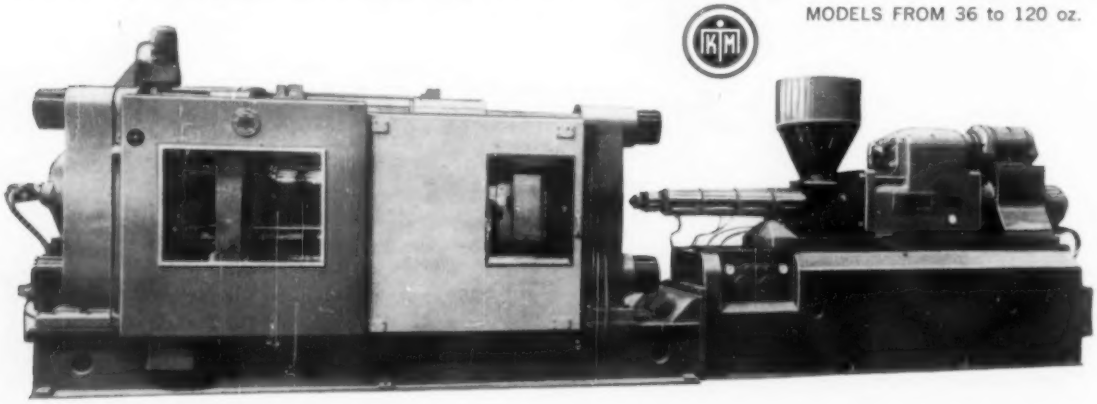

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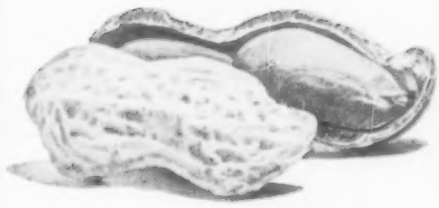

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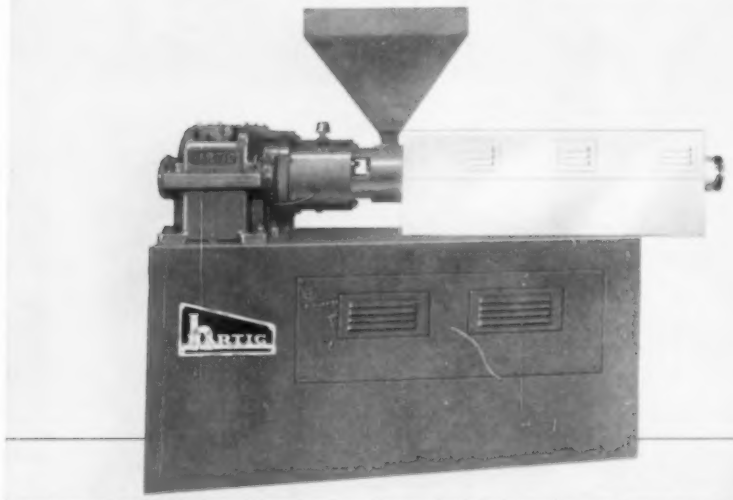

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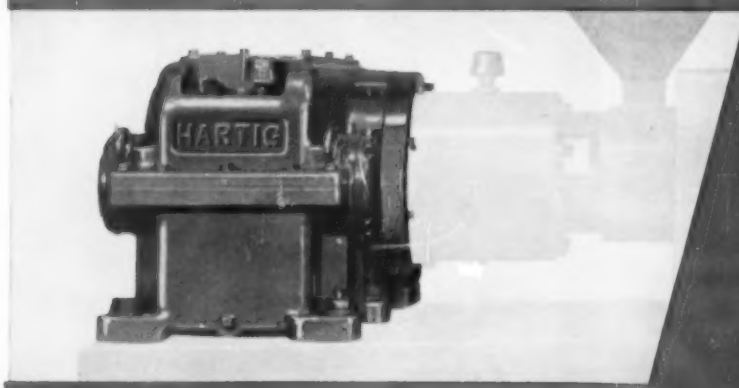

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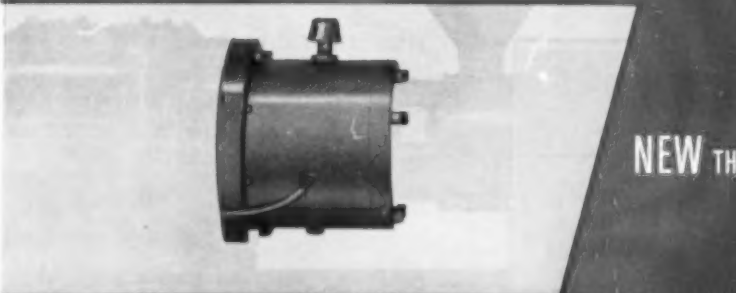

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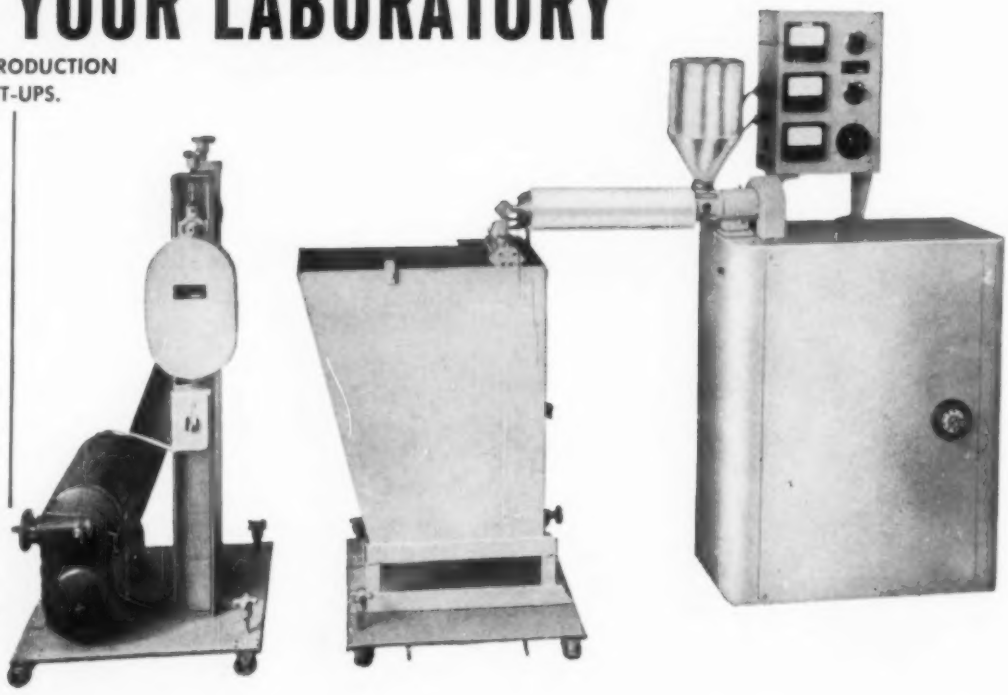

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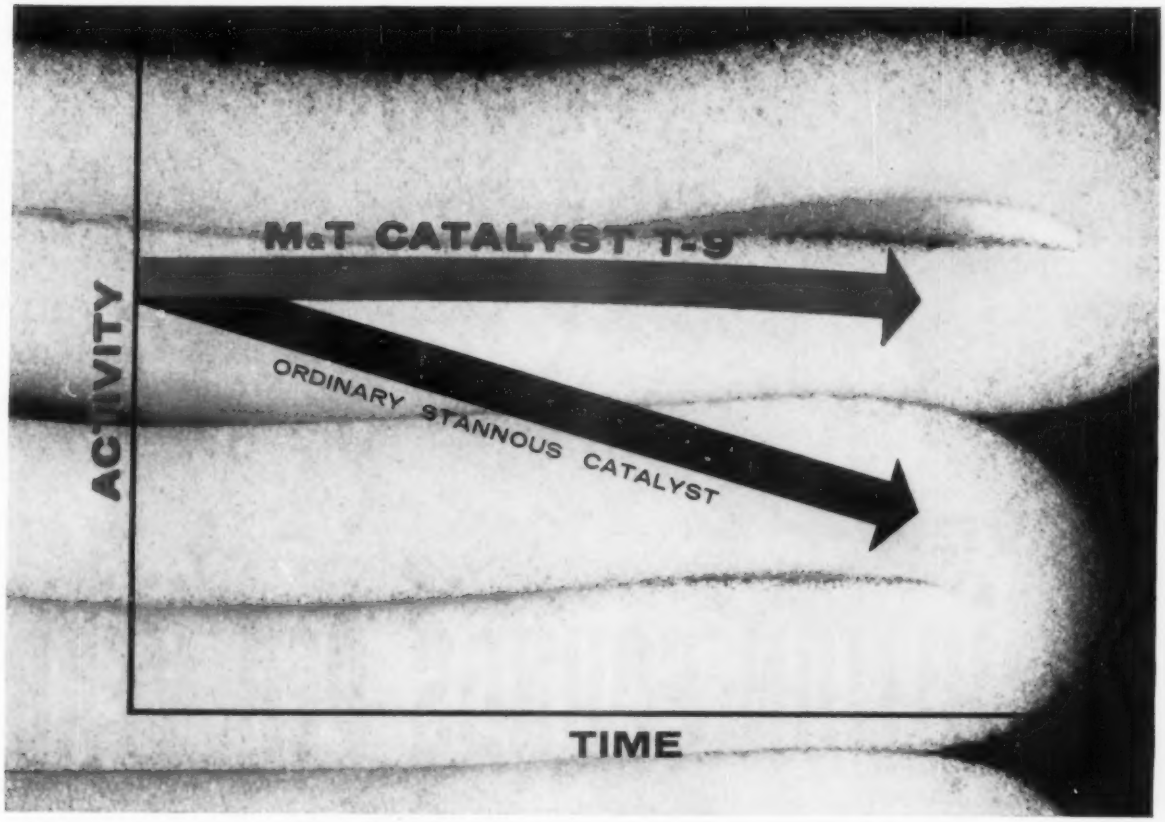

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FIRST CALL FOR PAPERS FOR SPE 18th (1962) ANTEC

Offers and abstracts for technical papers for SPE's 18th ANTEC to be held in Pittsburgh, January 30 to February 2, 1962, are requested immediately by George C. Kiessling, Technical Program Committee Chairman. To be considered for the ANTEC program, all offers and abstracts must be in his hands by March 1.

This request for offers and abstracts has been scheduled one month ahead of previous requests by the SPE Technical Program Committee to permit more time to develop a high quality program to meet the needs of the entire SPE membership. It is one of many moves made by the new SPE Technical Program Committee to improve ANTEC technical programs.

The Technical Program Committee is a new SPE international Committee formed to meet the urgent need for a continuous competent, international group representative of the entire Society to plan, organize, and implement ANTEC programs.

The sponsoring Pittsburgh Section is represented on the Committee by Chairman Kiessling and John E. Parks, General Chairman of the 18th ANTEC. Further information on the new Technical Program Committee will be found on page 1343, December 1960, issue SPE JOURNAL.

Technical papers for the 18th ANTEC must present new information, not heretofore presented or published elsewhere, and be of maximum scientific, engineering, artistic or crafts information relating to plastics.

An abstract of from 300 to 1,000 words must accompany every paper offer. Abstracts should contain enough information and data, even though in rough form, to give a clear indication of the scope and contents of the proposed paper. Completed technical papers are, of course, most welcome.

This request is being supplemented by a specific request to each of SPE's 16 Professional Activity Groups, and by a solicitation letter to SPE's entire membership.

Please mail your offers, abstracts and/or completed papers immediately to:

George C. Kiessling, Chairman
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Remember, March 1, 1961 is the deadline for consideration by the 18th ANTEC Committee.

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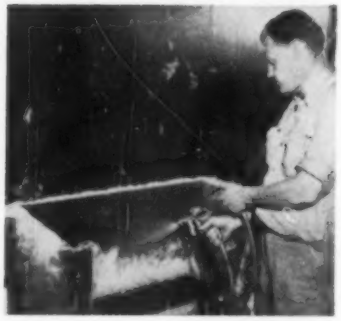

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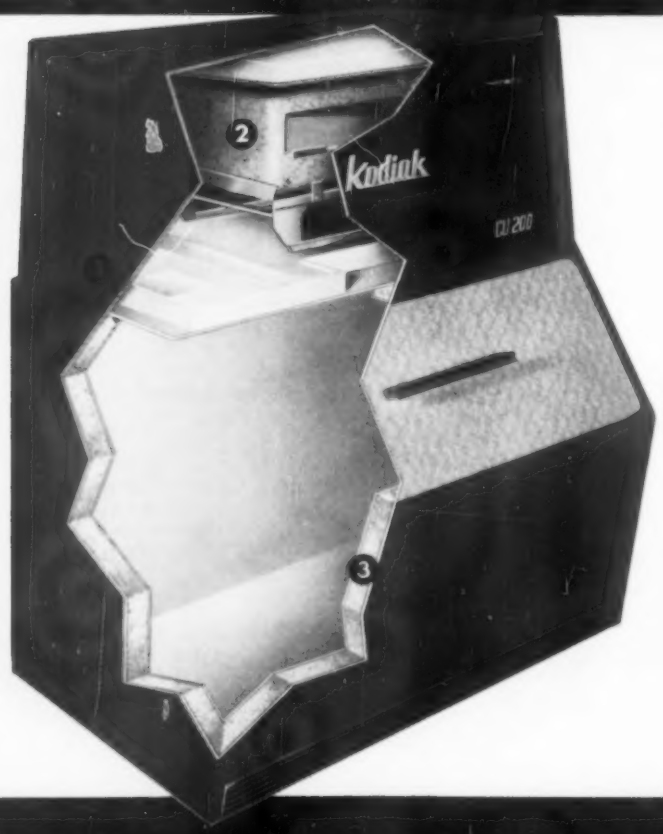

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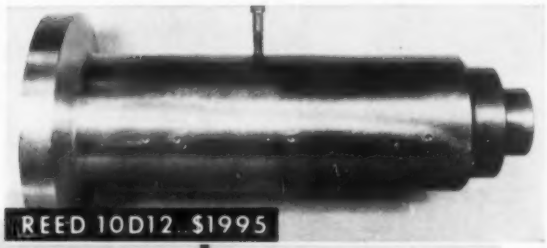

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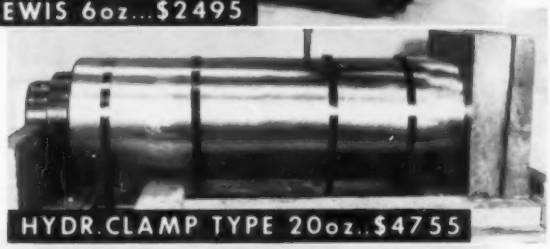

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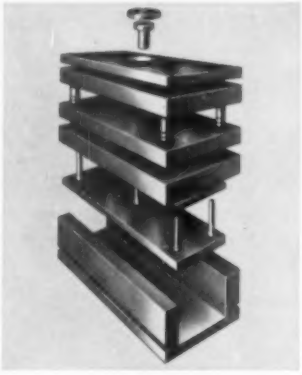

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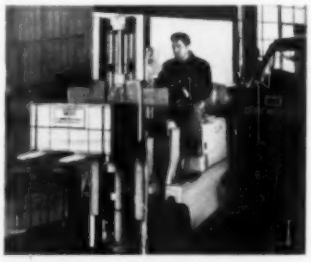

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MOLDMAKING

Is This Tolerance Necessary?

Unskilled design of parts, unrealistic tolerances, disregard for high levels of skills, add up to unjustified cost for molds and finished parts.

Mass production, as we have it today, had its origin in the nineteenth century and, today, as then, it is based primarily on the interchangeability of parts. Such interchangeability demands establishment of tolerance limits beyond which no component part can be accepted if the function of the assembly is not to be impaired. This, in its simplest form, is the principle of mass production. Unfortunately, over the years this principle has earned interest, compounded every era that a change in our living standards takes place. Over the many years, since the basic concept was established, the determination of what constitutes a limit of tolerance has shifted from the individual manufacturer to groups of professionals who have become sufficiently expert in their work to be able to set standards for all to follow. This is the desirable direction of progress, and certainly is the acceptable placement of responsibility.

Designers Inexperienced

But what do we do now that we have this working standard? In almost blind disregard for the high level of skills which produce the standards of performance, we entrust their interpretation to individuals who are not qualified, not trained, and, in fact, many times not the least bit cognizant of what is intended by these standards. To cite a typical case, a small nylon molded switch part specified a molded-in stainless steel bushing. The bore of the bushing was specified as .087 ± .001″–.000″, the O.D. .125 ± .003″ and the length .080 ± .002″—000″. The O.D. called for a diamond knurl .005 deep. To these basic dimensions were added requirements that clearly indicated the designer was completely inexperienced. The first was concentricity of the I.D. to O.D., given as .002″ T.I.R., a requirement that not only cannot be sensibly measured because of the knurl but also can serve no purpose since the O.D. is covered with nylon after molding and contributes nothing to the concentricity of the finished part. In fact, the bushing could be hexagon or square and still be satisfactory. The second requirement was squareness of bore to face, given as .0005″ T.I.R. but with a wall of .019″ the only method of measurement would be optical and even then the reference line for bore center would be practically impossible to establish! If the measurement is made mechanically a mandrel of precision squareness of level below .0001″ would be required and even then there is no certainty that the bushing could be positioned properly on the mandrel to be given a realistic measurement.

There were additional requirements, but these are all overshadowed by the most obvious error in the entire design. Why even bother with a stainless steel bushing when the nylon would be a more satisfactory bearing by itself?

A second component of the same assembly called for molding in a soldered unit of two U-shaped wires of .007″ and .005″ diameter respectively. The .007″ wire was formed in a U-shape wider than the .005″ so that the smaller U could be soldered at its base inside the larger U. The purpose of soldering was to provide electrical connection since the ends of the wires projecting from the molded part served as brushes on circular collector rings. The tolerances on these parts were utterly fantastic and the sizes made the entire assembly a nightmare in miniaturization. The irony of the situation is that few, if any, of the tolerances contributed to the control of performance of this unit, completely defeating the purpose of the tolerances. The cost—fabulous and completely unjustified.

Materials Selection—Another Problem

This illustration is just one of a series contained in just one complete sub-assembly of one section of one missile. Imagine, if you can, what must be the case in other sections, not plastic, but in metals, many of which are difficult to work and even more expensive to be toyed with than the plastic has been!

In the area of selection of materials the problem is much the same. Because too few designers are sufficiently familiar with proper selection of plastic compounds, the material salesman has a field day. All he has to do is show a properties chart with a value of tensile, compressive or flexural strength up in the rare atmosphere of metals and the material goes on the drawing as final and supreme. But no one asks "Can we mold this material to obtain these properties in this part? The molder must suffer the pain of questioning the design, possibly losing the order, because he knows from experience that such properties can be guaranteed only in an ASTM test, not in the final product.

Typical of this nonsense was the specification of a long-glass-fiber-filled material for a part requiring the molding of a very fine threaded hole.

The property chart listed two materials side by side, one with long fiber, the other with short fiber. Only after thousands of dollars of valuable time were lost would the engineer for the prime contractor consider the very first recommendation of the molder —that alternate materials be considered since it was impossible to guarantee that the fibers would mold with the resin around the small threaded core.

Some Answers to the Problem

These two cases are typical of the innocent yet very costly errors in judgment which plague not only the defense program, but also much of industry. Where the solution to such problems can be found is not a simple question. Certainly some action must be taken by the technical directors of the defense effort to stop this foolish waste, a waste which contributes heavily to the cost of the missile program and to many of the non-missile developments. There is no question that some requirements of performance demand close tolerance production, but the number is small compared to those actually appearing on drawings from the various military laboratories.

The major difficulty appears to stem from the delegation of responsibility of checking details to individuals whose backgrounds do not permit them to judge the requirements on the basis of performance. The experience which is needed for these decisions exists in the higher echelons of staff. The making of such decisions is considered a lower echelon function, so that the experience gained over many years is lost to the need for elevating experienced personnel to higher positions. If we could in some way reward this experience by some method other than elevation to administrative position, most likely the experience and talent would not be lost, and a happy situation for all concerned would result.

A very striking example of this elevation-to-administration occurred in a commercial organization in which small, intricate assemblies were manufactured. The individual, selected to be chief engineer, had an extensive background of very high performance in design. His knowledge of detail requirements was broad and he was able to carefully screen a design for flaws with little effort. The administrative level of his position was such that he spent most of his time in conferences discussing programs and planning, neither of which fell into the category of high level design skill. As a result, a small gear which had originally been metal, then later *machined* in nylon, was redesigned for molding in an acetal compound, but with no regard for the behavior of the material. The chief engineer had no time available to carefully examine this problem despite the fact that this component gear was the heart of their line of products. In fact, its performance was the divider between success or failure of their assemblies.

The responsibility for the design of this gear was left in the hands of a young engineer whose limited experience made him very cautious, resulting in specification of tolerances which later proved to be unnecessary. The outstanding error in this case was the omission of two dimensions of contour radius which the young engineer left in the hands of the molder. The molder, unaware of the need for precision in these dimensions, proceeded to design his mold and permitted the mold-maker to "blend in the radii." Fortunately, the moldmaker and molder both agreed that an attempt to duplicate the metal gear should be made and, thus, with an enlarged view of the contour, achieved a very close *match* to the metal. How ridiculous all this turned out to be when it was discovered that the two radii, not given on the drawing, were the dimensions controlling the performance of the gear.

Inspectors Play Key Role

Probably the most exasperating part of this overall lack of basic common sense is the final touch after material and dimensional design have been settled. That is the problem of inspection and quality control. The popular joke about inspectors is that they must reject something each day to prove they are doing their job. This could be an amusing and even happy condition if it had a semblance of truth. By the very theory of statistical quality control, the normal distribution curve shows 99.7% of a total population of parts produced under controlled conditions would fall within the limits of acceptance of the specification, thus, yielding .3% as justifiable rejects. If the inspector did his job by the laws of probability he should find some rejects from time to time, possibly each day. But, here again, we fall into that trap of classified jobs. The high caliber inspector soon becomes the chief inspector and he is replaced on the line by not an equal or reasonable facsimile thereof, but by a totally inexperienced amateur who "has to be broken in sometime," to quote the usual alibi.

Just such a case occurred in a plant making complete mechanisms for application in the field of atomic energy. This field by itself is so loaded with secrecy of a degree, so ridiculous, that it is amazing that any progress occurs. The design of the simplest part is guarded as though Einstein's theory of relativity would be exploded if the slightest information on this part was revealed. After all of the "high level" design is finished, and the parts manufactured, who does the inspecting? A man who not only cannot read the print completely, but who does not even know the meaning of some of the words describing the limits on the part. Added to this confusion, is the practice of many big companies, and all government agencies of using standards of dimensioning, standards of workmanship, and standards of inspection. These standards are excellent in that they provide a uniform basis for inspection. But does this inspector have a copy of these standards for his use? In most cases, no. The chief inspector has them, nicely filed where even the most efficient secretary cannot find them, and this poor fellow on the line must try to figure out what all of these limits mean. If he asks a question, he shows his inexperience. If he accepts a part without question, he is subject to possible reprimand. So he does what logic dictates—rejects it, and lets the vendor fight it out with the chief inspector or even the quality control manager.

How, then, can we protect ourselves from this unrealistic approach to product design? The responsibility in the case of the plastics industry falls squarely on the shoulders of each individual manufacturer. He must examine every application not in the light of a pie-in-the-sky profit, but in the legitimate use of materials, designs, and limits. Each part, each problem, and each process must be carefully viewed to make certain that the requirements are real, not imaginary, and that the performance desired is what will be obtained. The use of secrecy to cloak inexperience and ignorance is to be as highly deplored as the use of sub-grade materials or methods. Our industry must insist on examination of the performance requirements to make certain that the knowledge and experience we possess is intelligently applied. If we are to be regarded in the same league as other industries, we must display that *caliber* and prove that we are truly professional performers, and above all, are qualified to decide whether "This Tolerance is Necessary."

—— ■ ——

Edited by **Ernest J. Csaszar**
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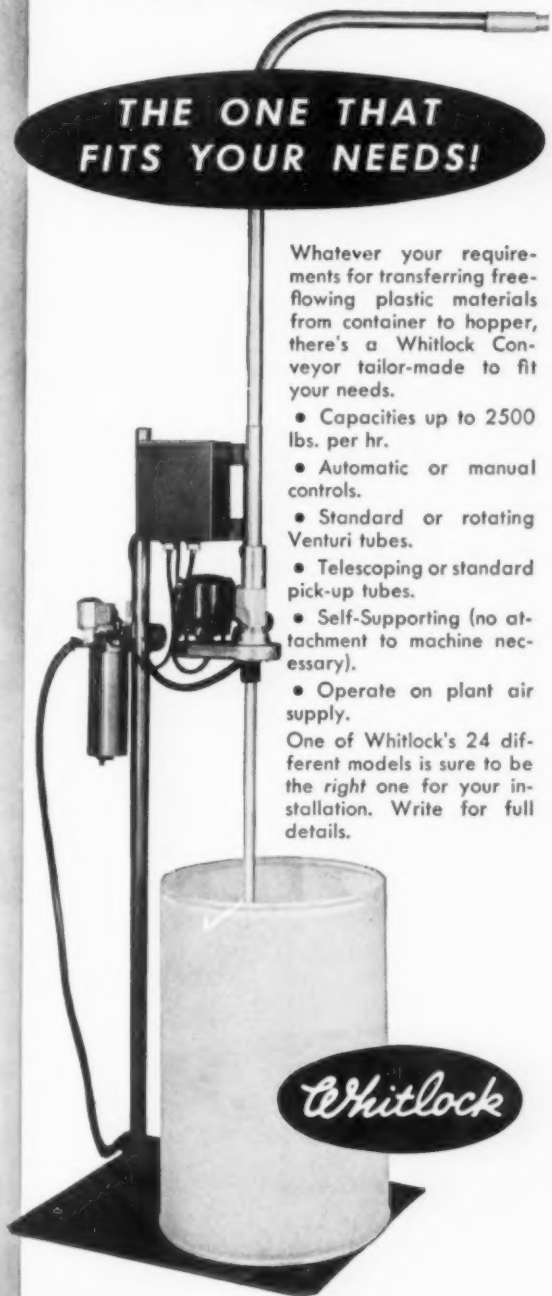

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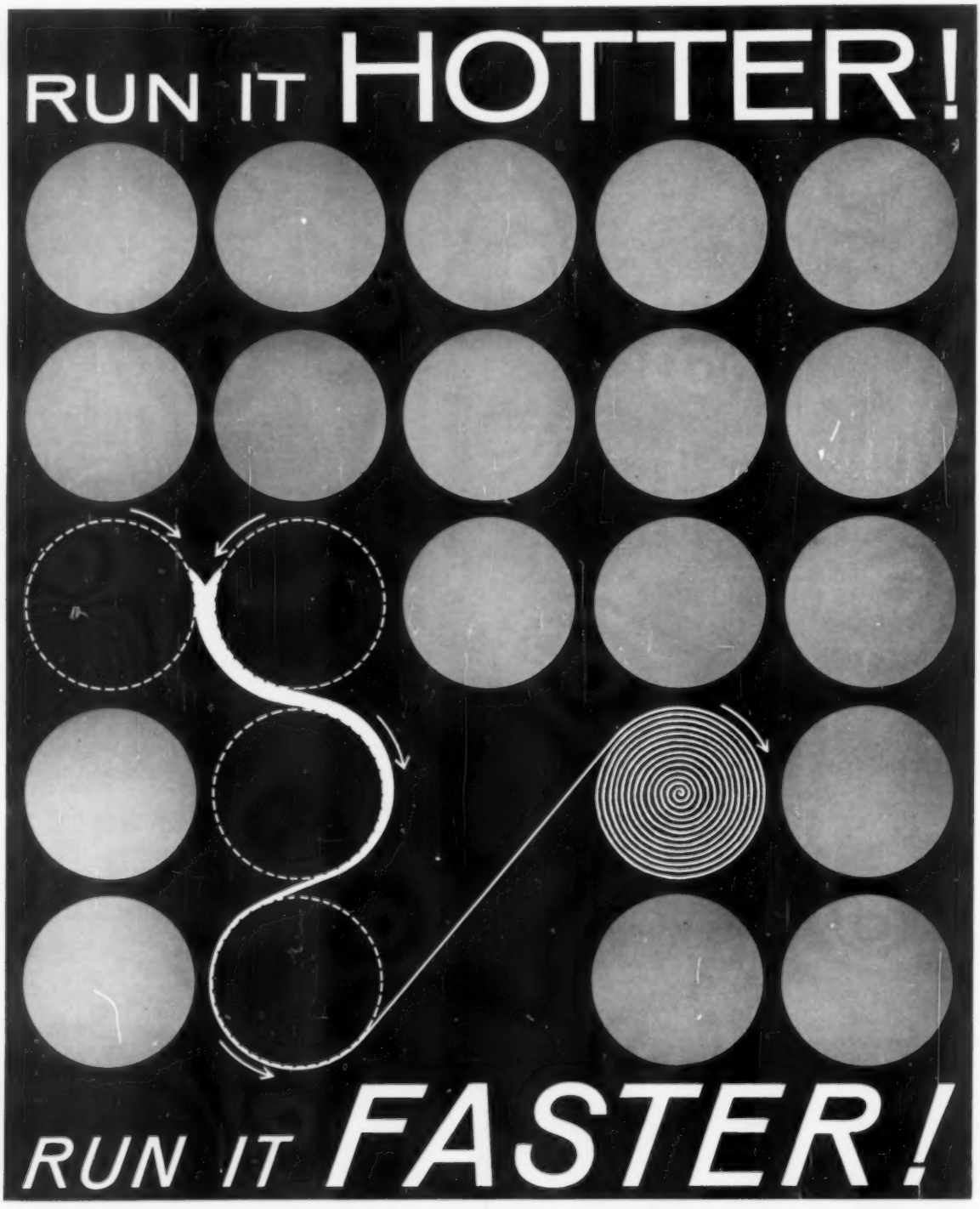

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An extensive program has been set up to acquaint plastics converters with the unique capabilities and business building opportunities of Lustran. Plastics converters are invited to contact the nearest Monsanto sales office for more information. Designers and manufacturers are invited to write for current data and progress reports to Monsanto Chemical Company, Plastics Division, Dept. 803, Springfield 2, Massachusetts.

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MONSANTO INNOVATOR IN **PLASTICS**

George P. Peterson

Materials Central, Wright Air Development Division, Wright-Patterson Air Force Base

REINFORCED PLASTICS

Properties of High Modulus Reinforced Plastics

Glass filament containing beryllium oxide increases modulus to approximately 17 million p.s.i.

The most important example of laminated structural composite materials of interest to the Air Force is reinforced plastics. Critical comparison of reinforced plastics with other structural materials has repeatedly demonstrated the basic advantages of reinforced plastics. The principal advantage is an extremely high strength-to-weight ratio which is superior to other structural materials including metals. Specific tensile strengths of as high as 24 x 10^6 inches have been obtained on optimum reinforcement oriented structural plastics. This is far in excess of most metals such as stainless steel, titanium, etc. which have specific tensile strengths of the order of 4-6 x 10^5 inches. In addition, structural plastics possess other excellent properties such as low thermal conductivity, good electrical properties, resistance to chemically corrosive environments, and simplicity of fabrication procedures.

One of the major areas where improvement has been most vitally needed has been the modulus of elasticity where most metals are consistently superior. Most reinforced plastics utilize a fibrous material which provides the bulk of strength and stiffness properties which are available in the laminate. "E" glass fibers have a modulus of 11 million

Table 1. Evaluation of YM31A High Modulus Glass Reinforced Plastics

Condition of Test	Direction With Warp	Strength (PSI)	Percent of Room Temp. Strength	Modulus (10^6 PSI)	Percent of Room Temp. Modulus
FLEXURAL TESTS					
Room	0°	89,800	—	5.00	—
Temp.	45°	62,700	—	2.62	—
2 Hr.	0°	79,300	88.3	4.79	95.8
Boil	45°	59,600	95.1	2.39	91.2
30 Days	0°	75,900	84.5	4.66	93.2
In Water	45°	57,200	91.2	2.39	91.2
½ Hr. @ 300° F	0°	44,200	49.2	3.69	73.8
COMPRESSIVE TESTS					
Room	0°	61,000	—	5.71	—
Temp.	45°	31,500	—	3.05	—
2 Hr.	0°	46,700	76.6	5.55	97.2
Boil	45°	30,200	95.9	3.03	99.3
30 Days	0°	44,200	72.5	5.52	96.7
In Water	45°	29,700	94.3	2.77	90.8
½ Hr. @ 300° F	0°	32,300	53.0	—	—
TENSILE TESTS					
Room	0°	64,500	—	4.76	—
Temp.	45°	31,300	—	2.90	—
2 Hr.	0°	62,100	96.3	4.58	96.2
Boil	45°	29,300	93.6	2.18	75.2
30 Days	0°	62,600	97.1	4.81	101.1
In Water	45°	28,400	90.7	2.01	69.3
½ Hr. @ 300° F	0°	51,400	79.7	—	—

Specific Gravity = 2.02
Percent Resin Content = 26.12

Table 2. Evaluation of "E" Glass Reinforced Plastics

Condition of Test	Direction With Warp	Strength (PSI)	Percent of Room Temp. Strength	Modulus (10^6 PSI)	Percent of Room Temp. Modulus
FLEXUAL TESTS					
Room Temp.	0°	70,700	—	3.69	—
	45°	55,000	—	2.05	—
2 Hr. Boil	0°	61,700	87.3	3.68	99.7
30 Days in Water	0°	67,800	95.9	3.69	100.0
½ Hr. @ 300°F	0°	40,700	57.6	2.53	68.6
COMPRESSIVE TESTS					
Room Temp.*	0°	43,900	—	4.37	—
2 Hr. Boil*	0°	45,700	104.1	4.10	93.8
30 Days in Water	0°	47,500	108.2	4.21	96.3
½ Hr. @ 300°F	0°	22,100	50.3	—	—
TENSILE TESTS					
Room Temp.	0°	63,800	—	3.49	—
2 Hr. Boil	0°	58,200	91.2	3.45	98.9
30 Days in Water	0°	57,900	90.8	3.30	94.6
½ Hr. @ 300°F	0°	40,800	64.0	—	—

Specific Gravity = 1.90
Percent Resin Content = 22.82
*Recheck Data Indicated Dry 53,700 PSI Strength -4.19 x 10^6PSI Modulus: 2 Hour Boil 46,100 PSI Strength-4.03 x 10^6PSI Modulus

psi and optimum laminates with proper fiber orientation can achieve a modulus of 7-8 million psi. This is far below the 30 million psi available from a commonly used metal such as steel. Research has consequently been concentrated on the development of filaments for use as reinforcements which will provide a much improved modulus and at least equivalent strength to reinforced plastics. Under a Materials Central sponsored research program, Owens-Corning Fiberglass Corporation has developed a high modulus glass which contains a small amount of BeO in the glass composition. Continuous fibers drawn utilizing this glass composition have equivalent strength and in addition, have increased the modulus properties to approximately *17 million psi.* Processes have been developed for twisting and plying these filaments into yarns and for weaving the yarns into various fabric patterns. The ultimate value of the high modulus filaments must, of course, be proved by ascertaining the improvement in the properties of reinforced plastic laminates. This article will concern itself mainly with a discussion of the properties obtained utilizing an optimum resin-finish combination with high modulus fibers as the reinforcement.

Properties of High Modulus Reinforced Plastics

A series of eight panels were fabricated by Owens-Corning Fiberglass Corporation which utilized Shell Chemical Co. epoxy resin (828) with m-phenylene diamine (CL) hardener in conjunction with high modulus (YM31A) glass. The YM31A glass was woven into the 181 style weave and the finish utilized was a special A-1100 type applied by Owens-Corning. The finished solution contained 2% A-1100 acidified to a pH of 6 with acetic acid. The plies of fabric were then dried at room temperature before rinsing with water to remove excess finish and residual salts. The final step involved a 20 minute drying period at 220°F in an oven.

The laminates were molded utilizing the following conditions:

Fabric Style—181 fabric, 14 plies

Finish—2% A-1100 (acidified to pH5)

Resin—Epon 828 epoxy resin

Hardener—m-phenylene diamine (CL)

Pressure—80 psi

Cure—1 hour at 250°F

Post Cure—1 hour at 375°F

A duplicate set of eight panels was also fabricated for comparative purposes utilizing "E" glass as the reinforcement. These panels were prepared in exactly the same manner as the high modulus panels described above with the only change being the type of fiber reinforcement.

Mechanical Property Data. The mechanical property evaluation of both the YM31A and "E" glass laminates included flexural strength and modulus, tensile strength and modulus and compressive strength and modulus. These tests were conducted in the as-received condition, after two-hour boil, after thirty days immersion in water, and at 300°F after ½ hour at 300°F. Tests are also under way to evaluate the fatigue and stress-rupture properties of YM31A laminates but data are not available at this time. The data for high modulus glass are as shown in *Table 1.* It should be noted that the YM31A laminates exhibited excellent strength and modulus properties for almost every test condition evaluated. Of particular note were the extremely high flexural and compressive strength properties. The most severe losses occurred in compressive strength after the two-hour boil and in the general strength properties obtained at 300°F after ½ hour exposure to 300°F. The modulus data were considered extremely satisfactory for every test condition particularly the compressive modulus which at room temperature was 5.71 x 10^6 psi. It should also be noted that while two-hour boil and thirty-day immersion definitely lower the strength properties, they affect the modulus data to a much lesser degree. The tensile strength and modulus properties, which basically involve an evaluation of fiber performance, indicated that the two-hour boil and thirty-day immersion had negligible effect on the high modulus laminates.

The "E" glass data are as shown in *Table 2.* It is important to keep in mind that these laminates were prepared in accordance with optimum fabrication and processing techniques developed for YM31A laminates. The properties obtained however, are considered to be indicative of the performance which can be expected of 828 CL "E" glass and A-1100 finish.

A review of the data in *Tables 1 and 2* indicate that YM31A laminates are consistently superior to "E" glass laminates in both strength and modulus. The increase in modulus was anticipated; however, the increased strength properties were considered of quite significant interest. The flexural and compressive properties in

the as-received condition were much superior to "E" glass. The modulus increase ranged from 23.5% for room temperature compression to 45.8% for tension after thirty days in water. This superiority in modulus was maintained even after exposures to temperature and water immersion. The only factor which marred the picture for the YM31A laminates on a comparative basis with "E" glass was the loss in compressive strength after two-hour boil and thirty-day immersion in water. The "E" glass laminates had superior strength retention and in this one case actually exceeded the strength properties obtained for YM31A. The room temperature data from these tests which indicated an advantage in both strength and modulus for YM31A laminates has also been corroborated by data from another source.

Electrical Data. One of the major areas where structural plastics have been utilized to date has been for aircraft and missile radomes. This has been due largely not only to the excellent strength properties but also to the electrical properties inherent in these materials. It was consequently considered essential to provide at least some initial data on the electrical properties of YM31A glass.

Bulk glass and laminate specimens were prepared and submitted to Dr. W. B. Westphal of the Massachusetts Institute of Technology, Laboratory for Insulation Research, who graciously agreed to conduct an evaluation of the electrical properties. The YM31A bulk glass samples were to be evaluated over a temperature range up to 500°C for dielectric constant and loss tangent. Data obtained are as shown in *Table 3*. This table also includes dielectric constant data which were obtained on bulk "E" glass samples at temperatures up to 300°C by WADD for a previous glass evaluation program.

The dielectric constant of YM31A glass in the as-received condition is considerably higher at 8.44 than "E" glass which has a dielectric constant of 6.56. Of particular interest, however, is the increase in dielectric constant of YM31A glass which occurs with an increase in temperature. At 500°C the dielectric constant of YM31A glass has increased to 9.26 and the loss tangent has increased by almost five fold from 0.0057 to 0.0250. A comparison with the available "E" glass data at temperatures of up to 300°C indicate twice the variation in YM31A as that obtained for "E" glass.

The data obtained for the YM31A and "E" glass laminates are shown in *Table 4*. The increased dielectric constant of the bulk YM31A glass is reflected in laminate form by the 5.47 dielectric constant at room temperature as compared to the 4.60 dielectric constant of the "E" glass laminates. The loss tangent of the YM31A laminates, however, are slightly lower than the loss tangent for "E" glass laminates. The temperature range which could be investigated was restricted due to the limitations of the Epon 828 resin system utilized. The dielectric constant and loss tangent data obtained at temperatures up to 300°F reflect slightly greater increase in dielectric constant for the "E" glass laminates than for the YM31A laminates.

Table 3. Room Temperature and Elevated Temperature Electrical Properties at 8.5 KMC of YM31A and "E" Bulk Glass*

Specimen	Condition of Test	Dielectric Constant	Average	Loss Tangent	Average
YM31A Glass	As Received	8.43		0.0057	
		8.45	8.44	0.0056	0.0056
		8.45		0.0055	
YM31A Glass	As Received	8.43		0.0057	
	100°C	8.50		0.0058	
	200°C	8.64		0.0063	
	300°C	8.82		0.0082	
	409°C	9.02		0.0129	
	500°C	9.26		0.0250	
"E" Glass	As Received		6.56		
	50°C		6.57		
	100°C		6.60		
	150°C		6.63		
	200°C		6.67		
	250°C		6.70		
	300°C		6.74		
	As Received (Repeat)		6.55		

* E Glass Data were derived from WADC TR 57-352.

Discussion and Interpretation of Data

The performance of high modulus fibers in woven laminate form (181

Table 4. Room Temperature and Elevated Temperature Electrical Properties at 8.5 KMC of YF31A and "E" Glass Laminates

Specimens	Condition of Test (°F)	Size of Specimen (In)	Dielectric Constant	Loss Tangent
YM31A Glass	78	0.40	5.47	0.0154
	78	0.45	5.52	0.0155
	78	0.50	5.45	0.0155
	110	0.50	5.49	0.0158
	158	0.50	5.54	0.0186
	222	0.50	5.62	0.0228
	248	0.50	5.65	0.0250
	300	0.50	5.69	0.0270
"E" Glass	78	0.40	4.62	0.0162
	78	0.45	4.57	0.0165
	78	0.50	4.60	0.0164
	119	0.50	4.67	0.0188
	167	0.50	4.72	0.0220
	210	0.50	4.76	0.0250
	258	0.50	4.82	0.0280
	300	0.50	4.87	0.0310

weave) are dependent to a great extent on use of optimum resin-finish combinations. The selection of 828-CL and A-1100 in this investigation was based on a complete evaluation program of various available resin and finish combinations. This involved investigation of commercially available materials such as Paraplex P-43 with Volan A and Garan finish, Vibrin 136A with Garan and Volan A finishes, Epon 1031 with Volan A and 112 finishes, CTL 91-LD with A-1100 finish and DC-2106 silicone resin with the 112 finish. The data obtained on these materials utilizing high modulus glass on the 181 style weave will soon be available in WADD Technical Report 60-24. A review of these data indicates that, while the modulus was significantly increased for every property, the strengths were generally lower than similar "E" glass laminates. This was particularly noticeable in the wet strength retentive data obtained for YM31A laminates. Resin-finish combinations which were optimum with "E" glass have much poorer properties when utilized with high modulus glass. This was principally attributed to the fact that the finishes were providing a very poor bond between the high modulus glass and the resin. Data which were obtained and are considered typical are contained in *Table* 5. It can readily be observed that these data are quite inferior to the Epon 828 A-1100 high modulus data presented earlier. This does not necessarily mean that the 828 resin system or the A-1100 finish are the only materials which can be utilized in conjunction with YM31A glass. It does mean that there still remains development work which the Plastics Industry must accomplish either to modify presently available resin-finish systems or develop new systems in order to obtain optimum results with high modulus glass. The data available utilizing 828-CL (A-1100 finish) merely prove that excellent data can be obtained.

Table 5. Comparative Data— YM31A vs. "E" Laminates with Epon 1031 and Volan A Finish

Condition of Test	Strength YM31A	Strength "E"	Strength YM31A	Strength "E"
FLEXURAL TESTS				
Room Temperature	86,200	93,800	5.32	4.18
2 Hour Boil	78,700	84,500	5.14	3.92
½ Hr. @ 500°F	22,500	34,700	3.04	3.16
192 Hrs. 500°F	20,600	15,400	2.66	1.56
COMPRESSIVE TESTS				
Room Temperature	58,800	55,800	3.83	3.10
2 Hour Boil	50,300	53,900	3.62	3.11
½ Hr. @ 500°F	11,400	16,300	—	—
192 Hrs. @ 500°F	5,900	6,500	—	—
TENSILE TESTS				
Room Temperature	54,600	60,500	3.99	2.93
2 Hour Boil	48,500	55,300	4.12	2.83
½ Hr. @ 500°F	45,800	38,200	3.58	2.39
192 Hrs. @ 500°F	28,500	32,900	2.85	2.73

Influence of Type of Reinforcement. The type of reinforcement has a decided effect on the strength properties which can be obtained with the YM31A glass. Data were obtained on several resin-finish systems with parallel strand reinforcement, 128, 143 and 181 style fabrics. These data are reported in *Table* 6 for the Paraplex P-43 polyester resin system and *Table* 7 for the Epon 828-CL epoxy resin system.

The data for the Paraplex P-43 system on 181 style woven fabric with Volan A finish are fairly indicative of the generally poor results mentioned earlier for resin-finish combinations which are not optimum. A review of the 143 style fabric and the parallel strand data, however, reveals that with these types of reinforcements the performance of Paraplex P-43 (Volan A) high modulus laminates are considerably superior to "E" glass laminates. This is of particular interest since it illustrates that it is a combination of several important factors which determines the performance of high modulus glass laminates. The YM31A fibers are stiffer than "E" glass fibers and based on the data obtained it is considered that yarn constrainment plays an important role in determining the effectiveness of YM31A glass as a reinforcement. This yarn constraint is caused by weave interlacings and the degree

Table 6. Effect of Type of Reinforcement on Paraplex P-43 (Volan A) YM31A and "E" Glass Laminates

Type Reinforcement	181 Style Fabric		143 Style Fabric		Parallel Stand*	
Glass Type	YM31A	"E"	YM31A	"E"	YM31A	"E"
FLEXURAL PROPERTIES						
Dry Strength (10³PSI)	59.2	71.8	120.1	109.1	—	—
Dry Modulus (10⁶PSI)	4.17	3.33	7.72	6.40	—	—
Wet Strength (10³PSI)	49.1	64.4	84.2	68.9	186.3	143.5
Wet Modulus (10⁶PSI)	3.10	3.20	7.37	5.77	9.91	7.38
COMPRESSIVE PROPERTIES						
Dry Strength (10³PSI)	52.4	47.8	60.8	55.0	—	—
Dry Modulus (10⁶PSI)	2.87	2.49	8.84	6.43	—	—
Wet Strength (10³PSI)	35.2	42.3	25.6	28.2	—	—
Wet Modulus (10⁶PSI)	2.82	2.36	8.53	6.36	—	—

* The Parallel Strand Laminates Utilized an 08 Treatment

of restraint is a function of the number of yarn interlacings and the bulkiness of the fill yarns. This means that plain woven material such as 128 style fabric imposes more constraint on woven yarns than an 8 harness satin weave (181 style fabric). Removal of this constraint by use of a crow foot satin weave (143 style fabric) or parallel strand reinforcement will result in considerably higher strength for YM31A glass laminates. This trend is quite noticeable in the Paraplex P-43 data.

A review of the 828 data indicates, as has been mentioned before, that Epon 828 is a better matrix material for YM31A glass than Paraplex P-43 regardless of the structure of the reinforcement. This is considered largely due to the fact that Epon 828 not only is a stronger adhesive than Paraplex P-43 but also because it is a more ductile material. This ductility allows better distribution of stresses during testing since the yarns which are embedded in the resin can deform to absorb the applied loads.

Specific Strength and Modulus Properties. The strength-to-weight and the modulus-to-weight data for any structural material are of far greater value to the flight vehicle designer than the actual strength and modulus values. Weight is of such great importance in selection of materials for structural applications that many materials which have high strength are of little value because of their high density. The fact that YM31A glass fibers are of higher density than "E" glass fibers is quite apparent in reviewing the specific gravity of the laminates prepared for this evaluation. The average specific gravity of the YM31A laminates was 2.02 as compared to the "E" glass laminates 1.90. Based on these specific gravities, the densities of YM31A and "E" glass laminates were calculated to be .0729 lbs./cu. in. and .0686 lbs./cu. in. respectively. Specific strength data were then calculated based on the comparative YM31A and "E" glass laminate properties. These data are reported in *Table* 8. As would be expected, the advantages of the YM31A laminates in strength and modulus are lessened to some degree. There is still, however, a considerable advantage for YM31A as far as modulus is concerned with a maximum increase of 27.2% for tension after thirty-days water immersion and a minimum increase of 15.9% for flexure after thirty-days water immersion. It is considered that the specific strength data do not impair to any great degree the basic advantages for using high modulus glass.

Table 7. Effect of Type of Reinforcement on Epon 828 (A-1100) YM31A and "E" Glass Laminates

Type Reinforcement	128 Style Fabric		143 Style Fabric		Parallel Strand	
Glass Type	YM31A	"E"	YM31A	"E"	YM31A	"E"
FLEXURAL PROPERTIES						
Dry Strength (10³PSI)	72.1	57.7	155.2	127.5	—	—
Dry Modulus (10⁶PSI)	3.83	2.81	7.96	5.83	—	—
Wet Strength (10³PSI)	60.7	50.5	130.7	108.7	252.5	225.8
Wet Modulus (10⁶PSI)	3.51	2.60	7.85	5.48	10.26	7.62
COMPRESSIVE PROPERTIES						
Dry Strength (10³PSI)	42.2	39.3	78.3	66.4	—	—
Dry Modulus (10⁶PSI)	4.78	3.51	8.63	6.02	—	—
Wet Strength (10³PSI)	33.5	35.6	50.5	49.5	—	—
Wet Modulus (10⁶PSI)	4.58	3.21	8.78	6.25	—	—

Summary and Conclusions

High modulus (YM31A) fibers in laminate form are generally superior to "E" glass laminates in strength and provide an increase in modulus of from 25% to 45% provided an optimum resin-finish combination is utilized. This superiority is lessened only slightly when considered on a specific strength and a specific modulus basis.

Table 8. Specific Strength and Modulus Properties* of YM31A and "E" Glass Reinforced Plastics

Condition of Test	Specific Strength (10³ in)		Specific Modulus (10⁶ in)		Percent Variation YM31A vs. "E" Glass	
	YM31A	"E"	YM31A	"E"	Strength	Modulus
FLEXURAL TESTS						
Room Temp.	12.31	10.30	68.55	53.76	16.3	21.6
2 Hr. Boil	10.87	8.99	65.67	53.62	17.3	18.3
30 Days in Water	10.41	9.88	63.89	53.76	5.1	15.9
½ Hr. @ 300°F	6.06	5.93	50.59	36.86	2.1	27.1
COMPRESSIVE TESTS						
Room Temp.	8.36	6.40	78.28	63.67	23.4	18.7
2 Hr. Boil	6.40	6.66	76.09	59.74	— 4.1	21.5
30 Days in Water	6.06	6.92	75.68	61.34	—14.2	18.9
½ Hr. @ 300°F	4.43	3.22	—	—	27.3	—
TENSILE TESTS						
Room Temp.	8.84	9.30	65.26	50.85	— 5.2	22.1
2 Hr. Boil	8.51	8.48	62.79	50.27	0.4	19.9
30 Days in Water	8.58	8.44	65.95	48.04	1.6	27.2
½ Hr. @ 300°F	7.07	5.94	—	—	16.0	—

$\frac{\text{Strength}}{\text{Density}}$ and $\frac{\text{Modulus}}{\text{Density}}$ Utilizing an Average Density of

$0.0729 \frac{\text{lbs.}}{\text{cu. in.}}$ for YM31A Laminates and

$0.0686 \frac{\text{lbs.}}{\text{cu. in.}}$ for "E" Glass Laminates.

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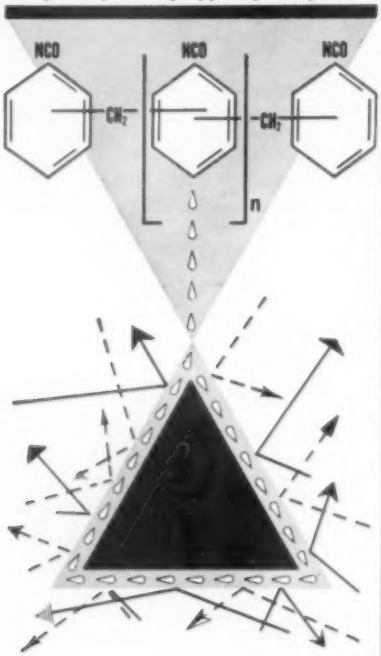

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The performance of high modulus glass laminates, particularly the strength properties, are greatly dependent on the resin-finish combination utilized and to date Epon 828 -CL epoxy resin with A-1100 finish has been the most successful combination evaluated. It is considered that further work by the Reinforced Plastics Industry is necessary to provide optimum resin-finish combinations patterned especially for use with the stiffer YM31A fibers.

The type of reinforcement has a definite effect on the properties of YM31A laminates since the minimizing of yarn constrainment problems increases the effectiveness of YM31A as a reinforcement. The YM31A fibers look particularly promising for parallel strand or filament winding applications since their performance with these types of reinforcements exceeds "E" glass even with non-optimum resin-finish combinations.

The electrical properties of YM31A are only slightly inferior to "E" glass in the lower temperature ranges, however, at higher temperatures from 300°C to 500°C the rapid change in electrical properties would make YM31A unsatisfactory for precision radar guidance applications. Further data, especially in laminate form, utilizing various resin-finish combinations are necessary before definite conclusions can be reached on the applicability of YM31A glass for radome usage.

The use of high modulus glass is considered to be definitely advantageous and is recommended wherever increased modulus is of prime importance. Action will be taken in the immediate future to provide specification coverage for the YM31A glass.

—— ■ ——

Edited by
George Lubin,
Grumman Aircraft Co.

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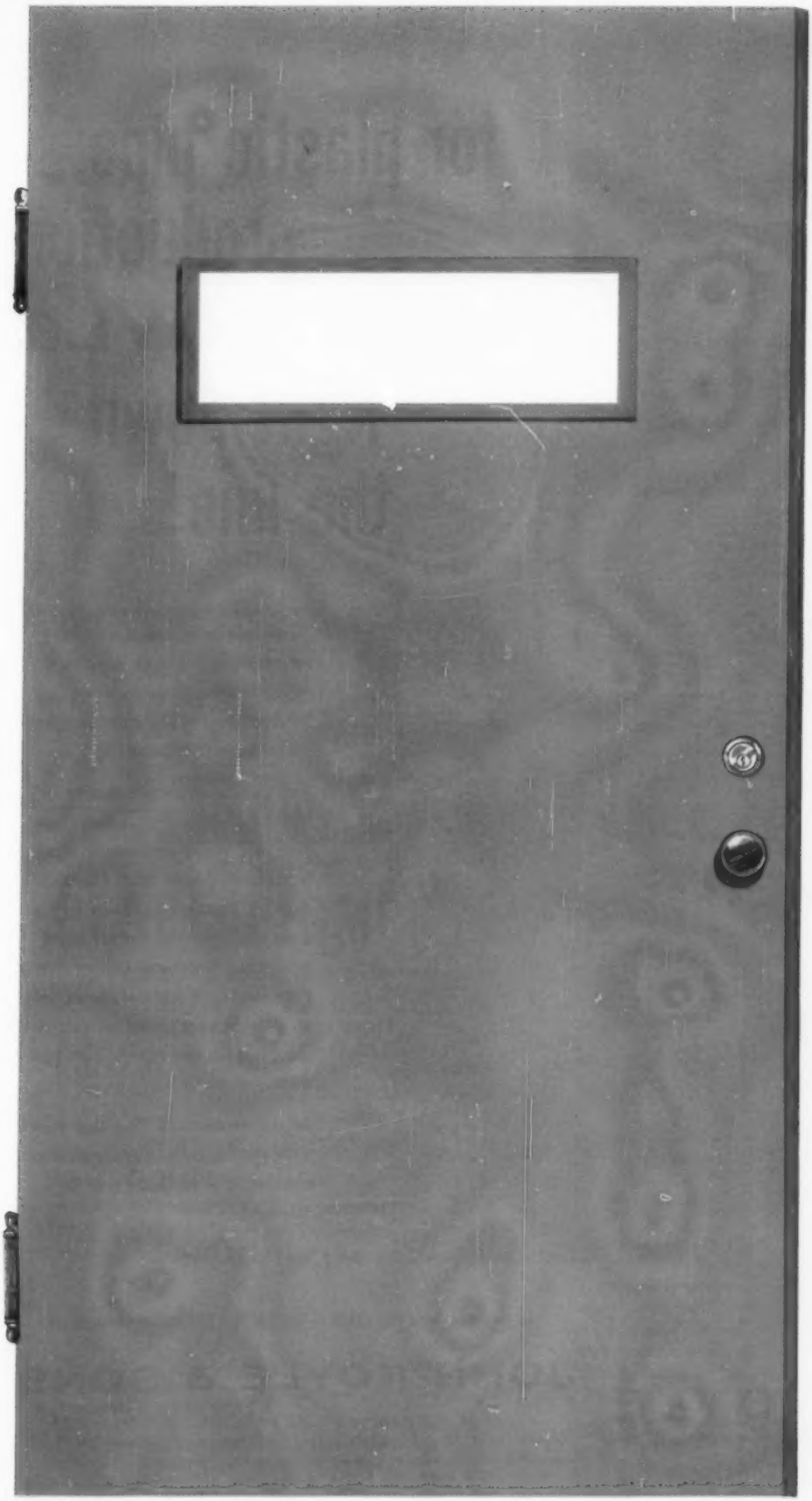

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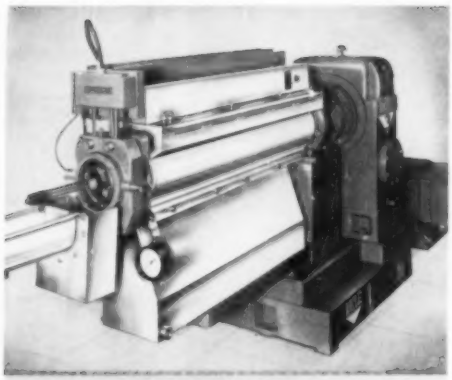

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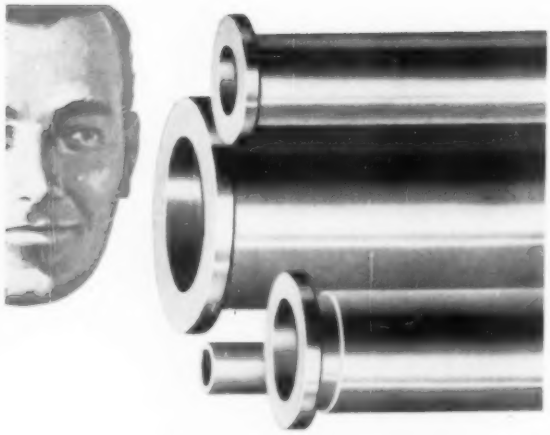

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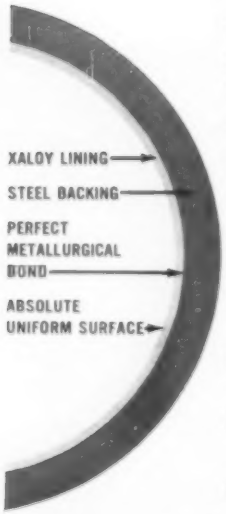

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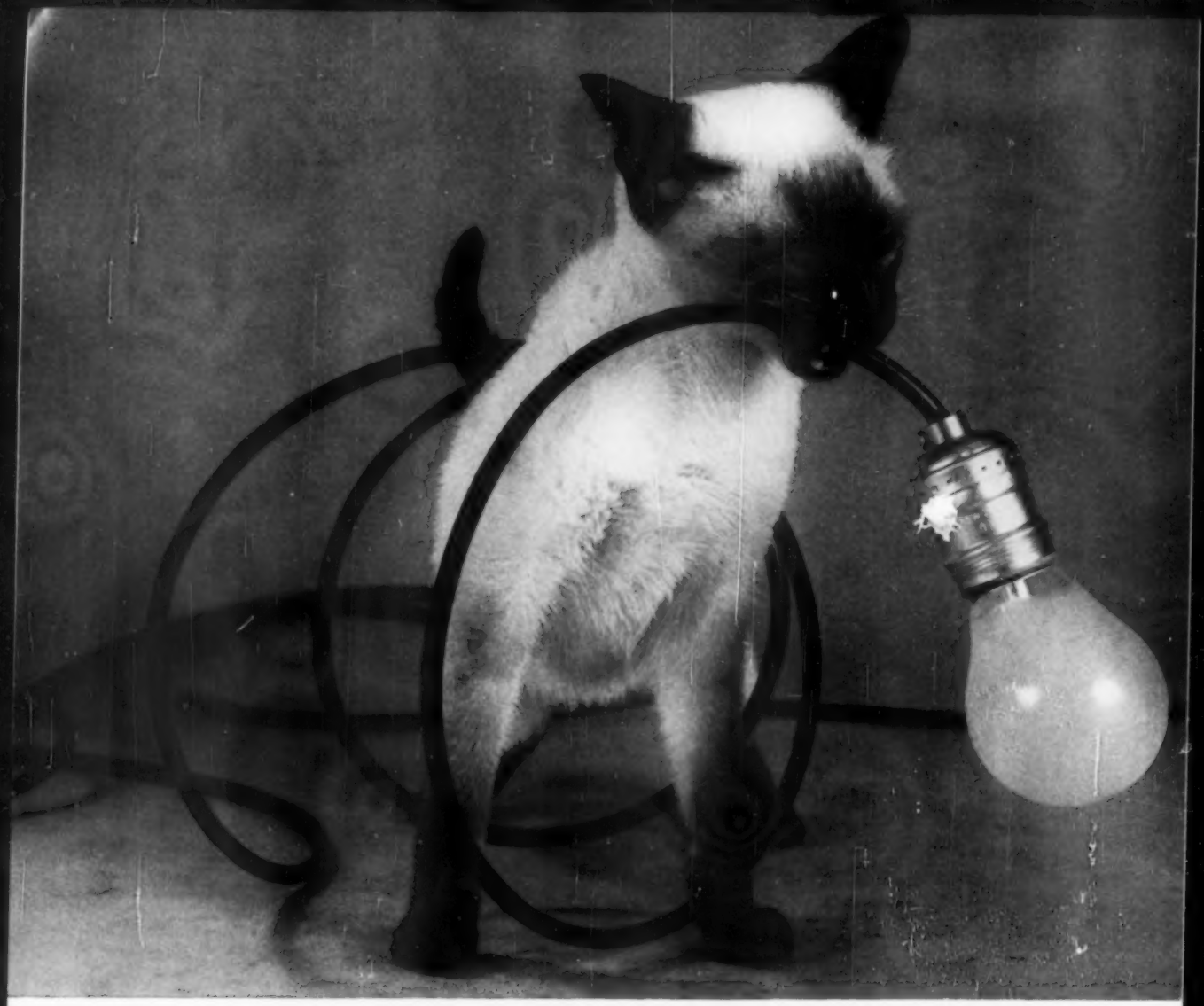

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SPE JOURNAL

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Polyvinyl Chloride Degradation and Stabilization

A review of the two major theories on the mechanism of degradation and stabilization—ionic and free radical theories

B. Baum

Union Carbide Plastics Company
Division of Union Carbide Corporation

Marvel (1) has established the structure of polyvinyl chloride* as primarily a linear polymer of "head to tail" configuration. If all of the chlorine atoms on the chain were secondary chlorines, the stability of the resin should be good. That degradation occurs at comparatively low temperatures suggests the presence of activating structures.

A consideration of the polymerization mechanism shows that thermally unstable structures are to be expected in the free radical polymerization of vinyl chloride (2). According to Bengough and Norrish (3) chain transfer to monomer is the predominant termination process in the polymerization of vinyl chloride. A β-chloro unsaturated structure would be expected from this mechanism. Termination by disproportionation is much less common than by chain transfer to monomer. Therefore, the α-chloro unsaturated groups which form by disproportionation would be present at a low concentration. Both mechanisms produce unsaturation at the chain ends. The organization studies of Wartman and Baum (4) have verified this.

Tertiary chlorides are present in polyvinyl chloride as shown by the work of Cotman. (5) By reductive hydrogenation, Cotman converted PVC to a hydrocarbon. The branch content was estimated by measuring the infrared absorption of the methyl group. His results indicate a branch content of twenty per molecule. These branches are presumably formed by chain transfer between a growing radical and an already formed polymer molecule.

Oxygen-containing structures are also present in PVC. In part, they arise from peroxide catalyst residues. In addition, oxygen-containing structures may be formed by polymerization in the presence of traces of oxygen or by post-oxidation of the polymer.

* Henceforth used interchangeably with PVC.

The following generalized structure contains secondary and tertiary chlorides, a catalyst fragment at one end and a β-chloro unsaturated grouping at the other (*Figure 1*).

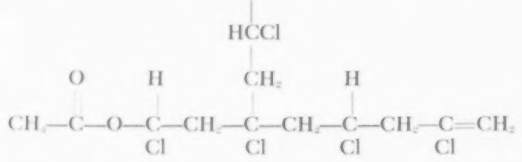


Figure 1. Generalized structure of PVC.

The most important decomposition reaction which occurs on heating polyvinyl chloride is loss of hydrogen chloride. It is well established that this loss of hydrogen chloride leads to the formation of a conjugated series of double bonds.

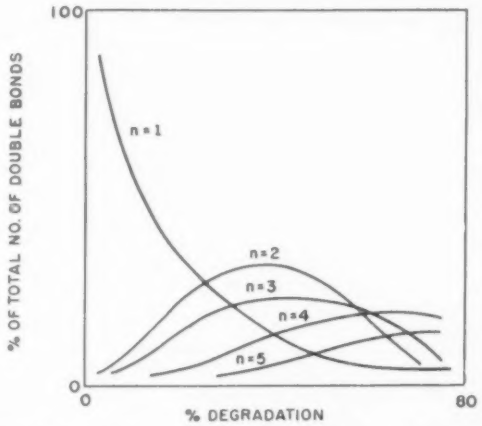


Figure 2. Distribution of double bonds among the various conjugated species.

Table 1. Effects of Degradation in N_2

Degradation Temperature °C	Moles HCl Loss/Mole Resin/4 Hours of Heating	Intrinsic Viscosity After 4 Hours Heating
—	—	1.10
130	0.10	1.10
150	0.53	1.10
170	4.77	1.20
190	27.5	1.60

—CH=CH—CH=CH—CH=CH—

The resultant conjugated polyene is colored. The depth of this color has been calculated by Boyer (6) to be related to the statistical distribution of the length of the conjugated chains (*Figure 2*). At least five to seven double bonds in conjugation are necessary for incipient color.

Thermal Decomposition in Nitrogen

When PVC is heated in nitrogen it progressively darkens as HCl is lost. The rate of HCl loss increases with temperature (see *Figure 3*). At the lower temperatures there is an induction period. This induction period could be the time necessary to build up sufficient energy to activate the weak spots in the molecule. After a long period of heating (not shown) the curve appears to flatten out. This may mean that the active centers which initiate HCl evolution are being depleted. The formation of structures interfering with dehydrochlorination is another explanation of the rate reduction.

These "interfering structures" could be crosslinks. Longer times or higher temperatures of heating cause the resin to lose more HCl and also cause an increase in viscosity via crosslinking (*Table 1*).

At sufficient HCl loss, the resin becomes insoluble in cyclohexanone.

Thermal Decomposition in Air

A different situation exists when the resin is heated under more practical conditions i.e., in the presence of air. As can be seen in *Figure 4*, the rate of HCl evolution is manyfold greater as the oxygen concentration increases. This indicates that new reaction sites for dehydrochlorination are being formed.

When PVC is heated in an inert atmosphere, crosslinking is the only molecular weight change that occurs. However, when the resin is heated in air, chain scission also occurs. Whether chain scission or crosslinking predominates depends upon the oxygen concentration, temperature and degree of HCl loss.

The most important distinction between degradation of PVC in nitrogen and oxygen lies in the effect of oxygen on color. The curve of *Figure 5* reveals that resin discolored by heating in nitrogen is temporarily bleached on subsequent heating in air. However, the greater HCl evolution in air leads eventually to more rapid resin discoloration. It is well known that strong oxidizing agents will decolorize aged PVC either on the mill or in solution. Apparently anything which attacks the double bonds, e.g., chlorine, will destroy conjugation and bleach the resin.

Effect of HCl on Resin Degradation

For years there has been controversy over the effect of the HCl evolved on the rate of degradation of PVC. Druesedow and Gibbs (7) concluded that the presence of HCl does not affect the rate of HCl loss when PVC is heated in nitrogen. In their experiment (*Figure 6*) the resin

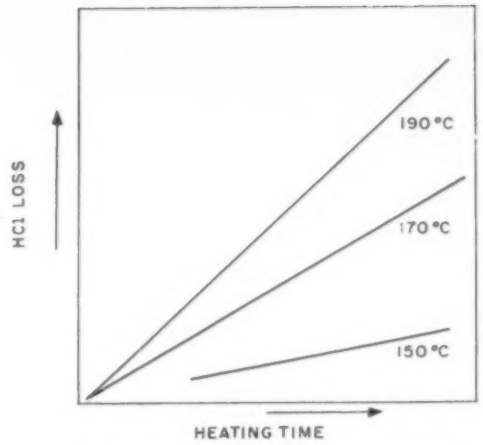


Figure 3. HCl loss vs. heating time in nitrogen at various temperatures.

was heated under nitrogen at 190°C. The nitrogen flow was discontinued for 5000 seconds. Flow was finally resumed. Quoting: "The total hydrogen chloride collected was the same as if the flow of nitrogen had not been interrupted. Apparently the thermal reaction in an inert atmosphere is not sensitive to hydrogen chloride concentration."

However, in the presence of oxygen, HCl catalyzes the evolution of acid. This is shown clearly in *Figure 7*. The rate of HCl evolution with stagnant air is almost twice the rate observed when the resin is being swept by air.

As is evident in *Figure 8*, color formation is catalyzed by acid. In this experiment HCl gas was bubbled through a 1% solution of PVC in dioctyl phthalate. When the HCl flow was stopped and air passed through the solution, the color was bleached.

Scarborough (8) et al have shown that the resin structure is affected by HCl even in the absence of oxygen (*Figure 9*). They measured the ultraviolet transmission of molded disks after they were heated in nitrogen and air with and without HCl. As previously discussed, there is much more change in air alone than in nitrogen alone. But the presence of HCl catalyzes structural changes in both nitrogen and air.

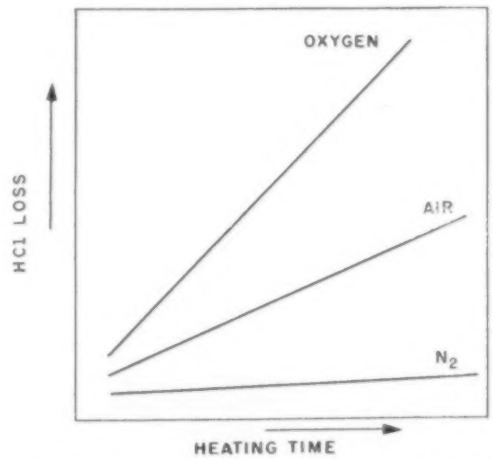


Figure 4. HCl loss vs heating time at various concentrations of oxygen.

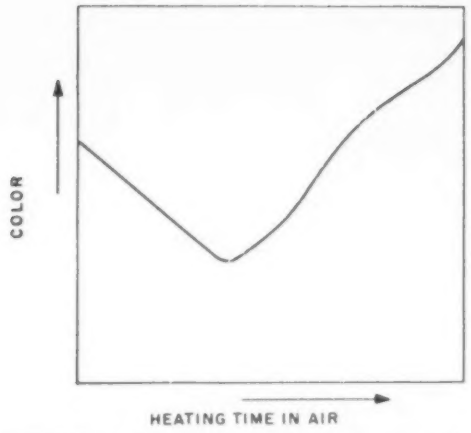


Figure 5. Effect of oxygen on color of resin previously discolored by heating in nitrogen.

Iron

Iron picked up during milling, or from any other source, is converted to the chloride. Ferric chloride not only catalyzes HCl evolution but also catalyzes discoloration. This is especially true in the presence of air and light. Brown spotting failure during light exposure has been traced to iron contamination.

Effect of Light

Reactions occurring during light exposure are similar to those found when PVC is heated in the presence of oxygen. Carbonyl is formed, revealing oxidation, and HCl and water are given off. The resin remains light colored until suddenly it turns dark. A resin discolored by heating in nitrogen is, at first, oxidatively bleached by light.

A material decomposes when exposed to light because it absorbs in the ultraviolet region of the spectrum. It is theorized that light is absorbed by PVC because of the presence of trace amounts of either oxygenated structures or unsaturation. Once the resin has been exposed to light it becomes sensitized to thermal degradation. *Figure 10* shows that PVC exposed to light loses HCl at a faster rate than an unexposed control loses HCl, both samples being heated in nitrogen.

MECHANISM OF DEGRADATION (IONIC)

Heating in Nitrogen

Where does the first molecule of HCl evolved come from? It is suggested that it is lost from a position which is inherently unstable due to some structural abnormality. As discussed previously, double bonds are present at the chain end. These structures are unstable (4) and would initiate dehydrochlorination through allyl activation of adjacent chlorines.

$$\sim CH{=}CH{-}CHCl{-}CH_2{-}CHCl{-}CH_2\sim$$
$$\downarrow$$
$$\sim CH{=}CH{-}CH{=}CH{-}CHCl{-}CH_2\sim + HCl$$
$$\downarrow$$
$$\sim CH{=}CH{-}CH{=}CH{-}CH{=}CH\sim + HCl$$

This decomposition, which has been called a "zipper" reaction, is responsible for the conjugated double bond structure and for the pink or yellow color of degraded resin.

The role of unsaturation in the original polymer is strikingly demonstrated by the effect of mild chlorination. The double bonds in the virgin resin were saturated with chlorine (4). In *Figure 11* the HCl loss rate of the virgin polymer is compared to the same resin after chlorination. The marked reduction in HCl loss shows that unsaturation in the virgin PVC initiates a considerable portion of the HCl evolved. The bleaching during chlorination is further evidence that chlorine saturates the double bonds.

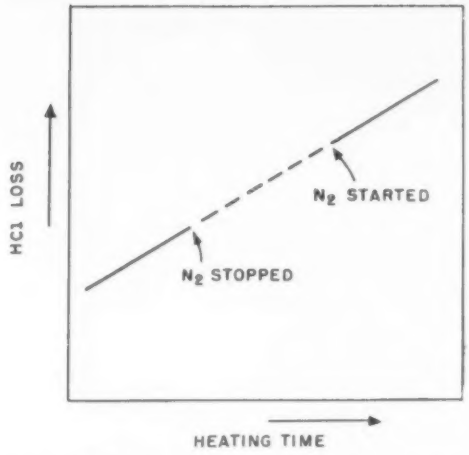


Figure 6. Effect of HCl on the thermal decomposition of PVC in nitrogen.

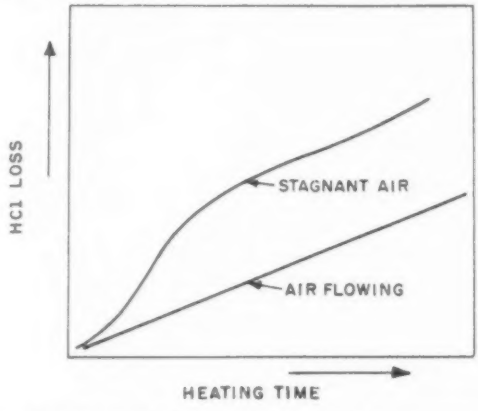


Figure 7. Effect of HCl on the thermal decomposition of PVC in the presence of oxygen.

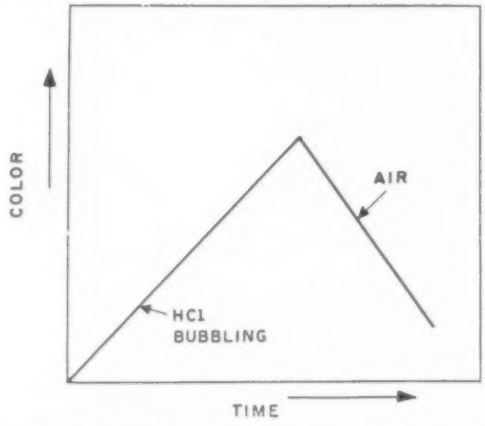


Figure 8. Effect of HCl on the color of a 1% solution of PVC in dioctyl phthalate.

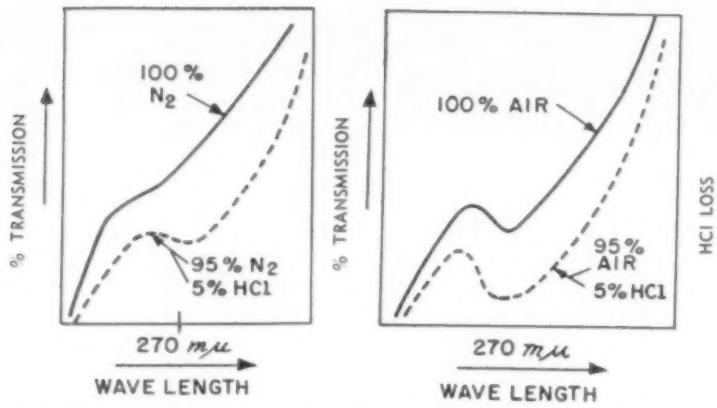


Figure 9. % transmission of PVC after heating under various conditions.

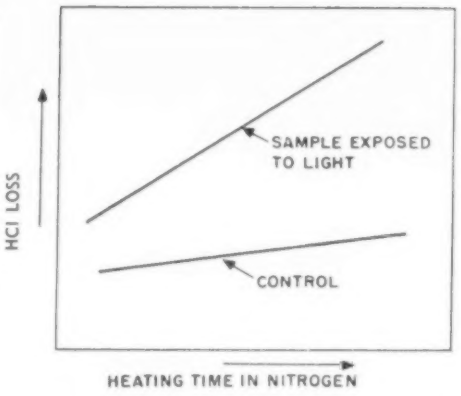
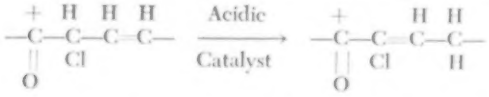


Figure 10. Effect of light exposure on rate of dehydrochlorination of PVC subsequently heated in nitrogen.

Another structural abnormality that should be capable of initiating HCl loss is branching. Cotman (5) converted PVC to a hydrocarbon by reductive hydrogenation and estimated a branch content of 20 per molecule by infrared. These branches are presumably formed by chain transfer between a growing radical and an already formed polymer molecule. Most of the branches are probably attached to the chain in a tertiary chloride-type structure (4).

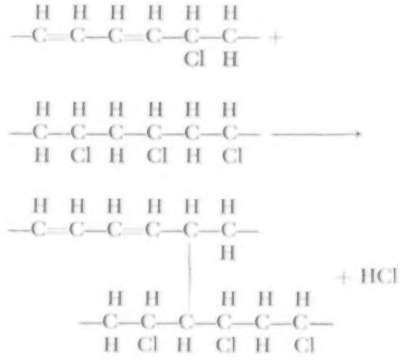
Catalyst fragments remaining at the chain end do not initiate degradation. Their removal by hydrolysis did not change the dehydrochlorination rate.

It has been theorized that the HCl evolved accelerates color formation by catalyzing double bond migration from isolated to conjugated. There is a so-called three carbon tautomeric shift and may occur in the resin as follows:



The second reaction would put the double bond in conjugation with the carbonyl and intensify the color through resonance.

Drusedow and Gibbs (7) suggest that the most probable mechanism by which crosslinking may occur on heating the resin in nitrogen is via cross dehydrochlorination between a point of high chlorine activity on one chain and a hydrogen atom on the other.



Heating in Presence of Oxygen

Oxidation puts oxygenated structures, such as peroxides or carbonyl, into the resin and destroys the polyene system. Both carbonyls and peroxides would labilize adjacent chlorine atoms and initiate and accelerate loss of HCl. The water formed during oxidation probably helps hydrolyze tertiary or other labile chlorines.

The autocatalytic effect of HCl in the presence of oxygen probably arises through catalysis of the decomposition of peroxides. Riley (9) et al show that the vapor phase decomposition of peroxides is accelerated by HCl.

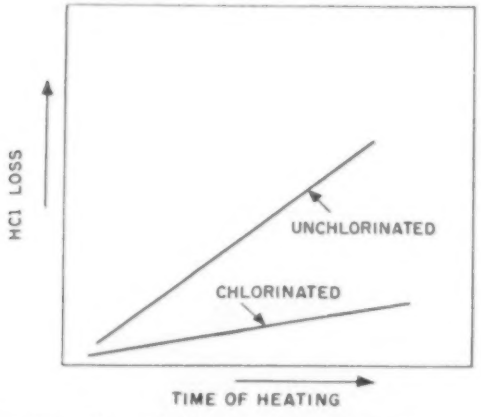


Figure 11. Effect of chlorination on HCl loss.

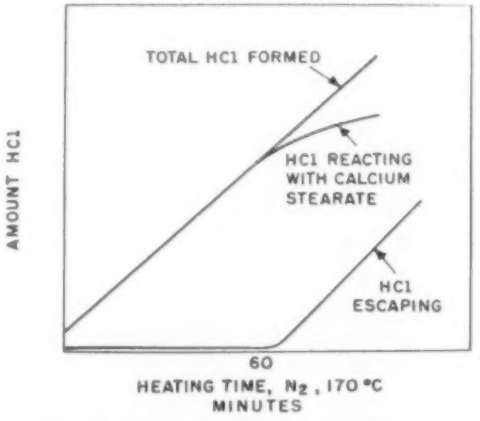


Figure 12. HCl reaction with cadmium stearate.

Table 2. Mill Stability and HCl Escape Rate

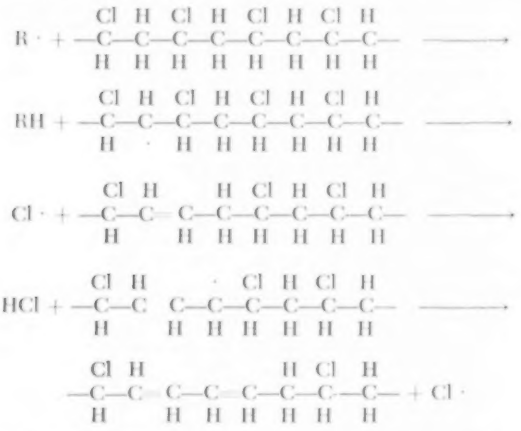
Stabilizer	Trade Name	HCl Escape at 60 min. Mg HCl/1000 Sq. CM/Hr	Reflectance at 450 Mu after 20 Min. Milling, %
Dibasic Lead Phthalate	Dythal	0.0	80
Dibasic Lead Phophite	Dyphos	0.0	80
Dibutyl Tin Maleate	—	0.0	80
Monohydrous Tribasic Lead Sulfate	Tribase	0.0	77
Coprecipitated Lead Orthosilicate and Silica Gel	Plumb-O-Sil B	0.0	76
Epoxidized Soybean Oil	Paraplex G-60	0.47	71
Dibutyl Tin Dilaurate	D-22	0.0	68
n-Hexyl Epoxy Stearate	—	4.3	66
Normal Lead Salicylate	Normasal	0.0	55
Calcium Stearate	—	0.78	43

MECHANISM OF DEGRADATION (FREE RADICAL)

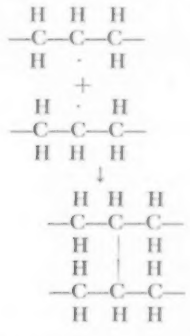
Heating in Nitrogen

Winkler (10) postulates a free radical mechanism to explain the evolution of HCl by PVC. Initiating radicals from a catalyst residue or from oxidation would probably attack a methylene hydrogen. The labile beta chlorine atom would be released to stabilize the molecule. This labile chlorine would then abstract another methylene hydrogen giving HCl and another labile chlorine atom. This chain reaction leads to the same conjugated structure previously discussed.

The following may be the sequence:



Crosslinking could occur via the combination of two free radicals in chain termination as shown below.



Another mechanism for the formation of a crosslink could be the addition of a free polymer radical to a double bond site on another chain.

Oxidation can lead to both crosslinking and chain scission simultaneously. The hydroperoxide formed as the first step in oxidation could lead to crosslinking through an alkoxy (R-O·) radical. Chain scission could also occur at the carbon atom next to the R-O-O· group.

THE ACTION OF STABILIZERS (IONIC MECHANISM)

A large number of materials have been tried as stabilizers. Antioxidants decrease HCl evolution and lengthen the life of the resin. However, they do not always seem to help color, probably because they prevent oxidative bleaching.

The usual PVC stabilizers, salts of heavy metals, react with the HCl evolved during degradation. Wartman (11) milled a number of stabilizers into a plasticized compound. He then heated molded disks in nitrogen at 170°C. The amount of HCl reacting with the stabilizers was determined by analyzing for ionic chlorides. The HCl escaping unreacted was also measured. In *Figure 12* is plotted the amount of HCl reacting and escaping vs time of heating in nitrogen for a compound containing cadmium stearate. It can be seen that there is a period of time during which no HCl escapes. The HCl has completely reacted with the cadmium stearate. The start of rapid HCl evolution corresponds to the time at which localized blackening of the otherwise excellent colored sample appears.

Cadmium stearate is typical perhaps of many heavy metal stabilizers. It reacts with HCl, yet at the same time it accelerates the rate of HCl evolution from the resin, i.e., the rate at which the resin degrades. Simultaneously, it promotes better short term color and thus must catalyze the bleaching rate of the polyene structures.

Table 2 (column 3) presents typical HCl escape-rate data (11) using a number of different stabilizers. Many of the stabilizers tested are not efficient HCl acceptors since they allow HCl to escape. Epoxides are among the least efficient.

Escape-rate data were used to determine whether there is a direct relation between HCl concentration in the compound and color stability. Column 4 of *Table 2* lists the color of the stabilized compounds milled for 20 minutes in air at 170°C. The lower the reflectance value the worse the color.

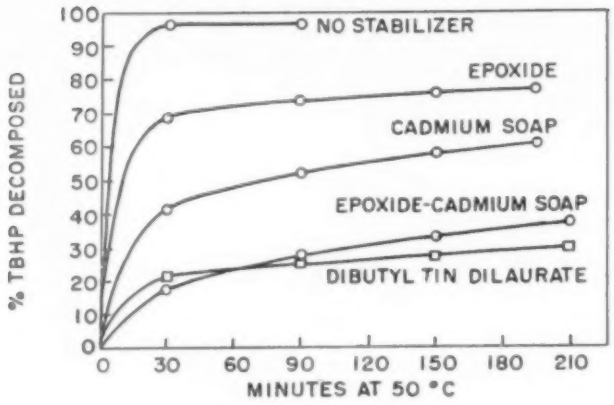


Figure 13. Effect of polyvinyl chloride stabilizers on the rate of decomposition of tert-butyl hydroperoxide in the presence of cobalt octoate.

These data (11) indicate that the efficiency of the HCl accepting reaction is certainly not the only factor determining the discoloration obtained with a stabilizer. All the best color stabilizers are efficient HCl acceptors but, on the other hand, a good acceptor can give poor color stability—e.g., normal lead salicylate.

Normal lead salicylate has been reported to be an antioxidant, (11) and its poorer color stabilizing efficiency may therefore be due to its inhibition of oxidative polyene bleaching (11).

Many authors have suggested that heavy metal stabilizers act as oxidation catalysts. Oxidation is probably the complicating factor that prevents a direct relation between acid evolution and color formation. In practice not only must oxidation of the resin be taken into account but also the oxidation of the plasticizer. This latter reaction can affect the physical properties of the resin compound.

Thus it is obvious that the mechanism by which PVC degrades is very complex.

THE ACTION OF STABILIZERS (FREE RADICAL MECHANISM)

Kenyon (12) has presented evidence that the PVC stabilizer dibutyl tin diacetate functions by a free radical mechanism. He exposed a PVC compound containing C14-butyl-labelled dibutyl tin diacetate to ultraviolet light. After irradiation the C14 butyl was found in the PVC. Kenyon proposed the following mechanism as a possible explanation.

$$R\cdot + (C_4H_9)_2\,Sn\,(OA_c)_2 \rightarrow RC_4H_9 + C_4H_9\,Sn\,(OA_c)_2$$

The butyl group has reacted with the PVC radical R·. Kenyon also suggests that the addition of the butyl group to the polymer radical blocks further crosslinking and oxidation at this point.

Winkler has demonstrated that many PVC stabilizers can act as free radical scavengers. The basis of his experiment is as follows:

Hydroperoxides are decomposed catalytically by metal ions such as cobalt, which can exist in two valence states. Quoting him (10): "To demonstrate the influence of polyvinyl chloride stabilizers on this reaction, the following experiment was run. Glass-stoppered flasks were charged with 90 ml. of toluene (95 ml. when no stabilizer was added), 5 g. of stabilizer, 5 ml. of tert-butyl hydroperoxide, and 0.2 g. of cobalt octoate (6.0 weight-% cobalt). As soon as the cobalt was added, the flasks were placed in a thermostated water bath at 50°C., and the drop in hydroperoxide concentration was followed by withdrawing samples and determining hydroperoxide contents. (Results are shown in *Figure 13.*) Decomposition was rapid in the absence of stabilizers and was retarded the most by dibutyl tin dilaurate, which is recognized as an excellent stabilizer for polyvinyl chloride. The epoxide used was a condensation product of Bisphenol-A with epichlorohydrin. The combination of the epoxide with a cadmium compound is a superior stabilizer relative to each used separately at the same total loading. This combination approaches dibutyl tin dilaurate in effectiveness as a polyvinyl chloride stabilizer and also as a stabilizer in the hydroperoxide-cobalt system."

Conclusions

Which theory is correct? Oxidation undoubtedly occurs by a free radical mechanism and the ionic theory can not cover this. On the other hand, it is difficult to imagine inorganic alkaline PVC stabilizers operating by a free radical mechanism. The free radical theory does not seem to cover the role of stabilizers as HCl acceptors. It also does not allow for the possibility of weak points in the molecule being responsible for the initiation of acid evolution. It would appear that both theories are needed to fully explain all that happens in the degradation and stabilization of PVC.

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The Measurement of Polyethylene Degradation by ZST Test

Theodore H. Meltzer
and John J. Muldrew

The Carl F. Norberg Research Center
The Electric Storage Battery Company

The oxidative degradation of polymeric materials such as polyethylene is known to involve a complex series of reactions. Chief among these are the two competing reactions of cross linking and chain scission (1). The first of these serves to build up the molecular complexity of the polymer chains. The second has the exact opposite effect. Because these reactions proceed competitively, at any moment during its oxidative degradation a polymer will possess the molecular structure which reflects the dominant reaction. Since the polymeric properties relating to viscosity and flow depend upon the size, shape, and complexity of the polymer's molecular chains, any alteration in the molecular architecture, as through oxidative cross linking or chain scission, results in a change of viscosity and flow characteristics. Cross linking aggrandizes molecular complexity and, hence, increases viscosity and reduces flow. Chain scission has the reverse effect.

As a consequence, it is possible to follow the oxidative degradation of polyethylenes by the use of the melt index determination. Melt index is a measure of plastic flow over a ten minute period under carefully defined conditions, namely, at a temperature of 100°C, under a load of 2160 grams, through a cylindrical orifice 0.0825 inches in diameter and 0.315 inches in length (2). As oxidation alters the polymer's size and shape through the agency of cross linking and chain scission, the extent of plastic flow is found to vary. Unfortunately, the use of melt index finds severe limitations in practice. In the case of many polyethylenes the cross linking proceeds to only a small extent before the plastic's flow is decreased to the point where it becomes immeasurable by melt index. In others, the predominance of chain scission causes the degraded plastic to flow too readily for melt index to be of value.

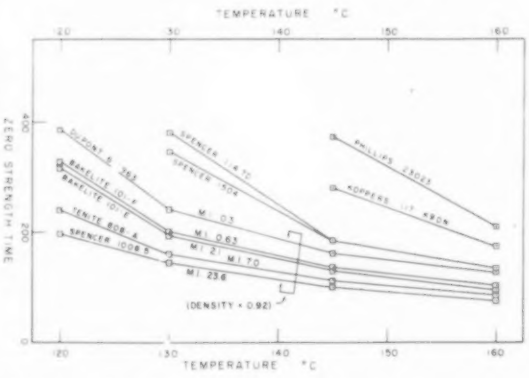


Figure 1. Zero Strength time vs test temperature

ZST Procedure

The development of the zero strength time test, a description of the commercially available instrument designed for its application, and an account of its use in the grading of polyethylenes are described in the literature (3, 4). **The ZST test involves placing vertically into a preheated furnace, a standard notched strip of polyethylene supporting a standard weight, and measuring the time until the plastic has zero strength as evidenced by rupture of the sample at the notch under the burden of the weight.** The relation between ZST values and test temperatures for several polyethylenes is presented in *Figure 1* (5). It is seen that the differentiation among ZST values is minimized by increasing temperature. For conventional polyethylenes a suitable test temperature is 130°C which under a load

Table 1. Typical ZST Data for a Polyethylene Resin

Alathon 10—Mill Oxidation

Time on Mill	Sample Thickness	ZST @ 130°C.
0 Minutes	62.5 Mils	233
0	63.0	230
0	63.0	214
30	62.0	210
30	62.0	212
30	62.0	200
60	62.0	210
60	62.5	219
60	63.0	223
60	63.0	233
90	62.5	220
90	63.0	227
90	63.0	224
120	62.0	213
120	62.0	206
120	62.0	225
120	62.0	219
150	62.0	213
150	62.5	218
150	62.5	224
180	62.5	220
180	63.0	242
180	63.0	230
210	62.5	273
210	62.5	285
210	63.0	254
210	63.0	311
240	62.5	416
240	62.5	350
240	63.0	330
270	62.5	410
270	62.5	415
270	63.0	485

of 7.5 grams gives time intervals in the neighborhood of 200 seconds. A test temperature of 160°C suffices for the linear polyethylenes. Ordinarily the standard test strips are cut from a plaque compression molded between polished plates using spacers of such height as to give a plastic thickness of 62.5 mils. The plastic plaque resulting from such a molding procedure is usually not quite uniform in thickness. This necessitates a selection of suitable samples from those available, or a plotting of time vs thickness as shown in *Figure 2* to give the ZST value for the 62.5 mil thickness. In this work we have preferred to minimize thickness variation by compression molding the plastic using a flash type mold having a cavity with a depth of exactly 62.5 mils. Samples cut from the plaque are characterized by their thickness as measured at the notch. Typical data for a polyethylene resin are shown in *Table 1*. It is seen that the thickness variation is ± 0.5 mil.

The Kellogg ZST Tester used in studies of this sort contains two furnaces (4). It is found that a slight variation between the two furnaces of an instrument may exist, as shown in *Table 2*. Usually insignificant, this furnace variation was nevertheless eliminated in our work by the exclusive use of one furnace alone. It should be noted, however, that the temperature recorded in the thermometer well of the instrument does not precisely define the temperature of the furnace. This is shown in *Table 3*. This would be of importance, however, only where absolute rather than relative ZST values are required.

Table 2. Effect of Furnace Temperature Variation on ZST Values

Resin	120°C. Left	120°C. Right	130°C. Left	130°C. Right	145°C. Left	145°C. Right	160°C. Left	160°C. Right
1	318	324	198	207	135	140	105	106
2	—	—	370	390	184	191	130	133
3	—	—	340	350	182	191	131	134
4	—	—	—	—	273	283	173	177
5	—	—	—	—	351	393	207	216
6	390	387	235	247	155	171	123	130
7	317	337	196	202	135	138	101	102
8	304	328	197	201	128	132	97	99
9	233	247	159	163	112	114	86	88
10	194	204	141	146	98	102	76	80

The relationship of ZST and melt index has been described as being generally of an inverse nature (3). It is further shown by *Figure 1*. On this basis it was to be expected that as the melt indices of polyethylenes were altered by the cross linking and chain scission of progressive oxidation, the ZST values would also change.

A number of polyethylene resins were subjected to oxidation either by being milled at 160°C, or being exposed as 60-80 mesh powder to fuming nitric acid at 50.5°C. Incrementally oxidized samples were obtained by removal from the mill or acid after progressively longer residence times. The oxidized resins were then molded into the plaques from which ZST samples were cut. This was done using a two plate, flash type, 2 x 3 x 1/16 inch, single cavity compression mold and a hand operated Carver Laboratory Press. For DuPont polyethylene Alathon 20, for example, the molding cycle involved a sample weight of six grams, a temperature of 105°C, and thrice repeated pressure applications of 2500 psi for two minutes each, alternated with pressure releases. This was followed by a peak pressure of 5000 psi which was allowed to decrease to 2000 psi, before cooling to 50°C and a final release was effected. For linear polyethylenes, such as DMDA, a similar cycle but at a temperature of 122°C was used. Using this procedure the ZST data presented in *Figures 3*

Table 3. Comparison of Furnace and Thermometer Temperatures

Thermometer Reading Left Furnace	Thermometer Well	Thermometer Reading Right Furnace
90°C	95°C	90°C
100	105	100
111	114	110
120½	124	120
131	134	130
141	143	140
151	154½	150
158	160	157
160	161	159
161	162	160
92	95	91
101	104	100
131	134	130
141	143	140
151	153	150
160	160½	159
159	160	158½
159	160	158½

Figure 3. Variation of ZST & melt index with extent of oxidation

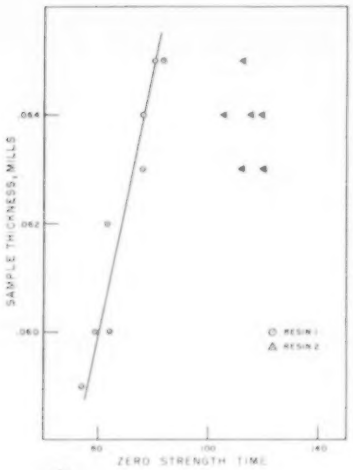


Figure 2. Sample thickness vs ZST values

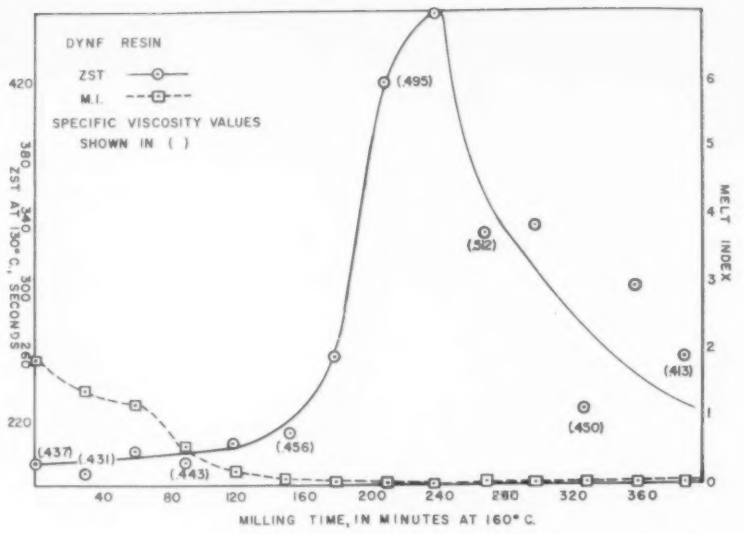
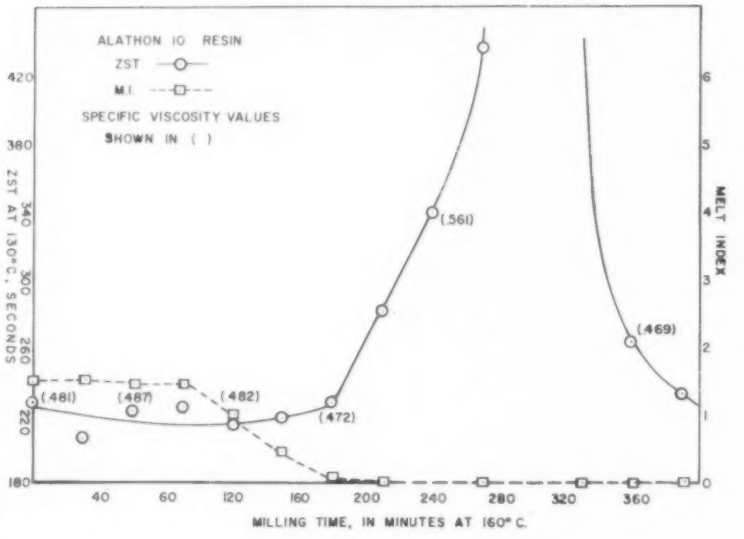


Figure 4. Variation of ZST & melt index with extent of oxidation

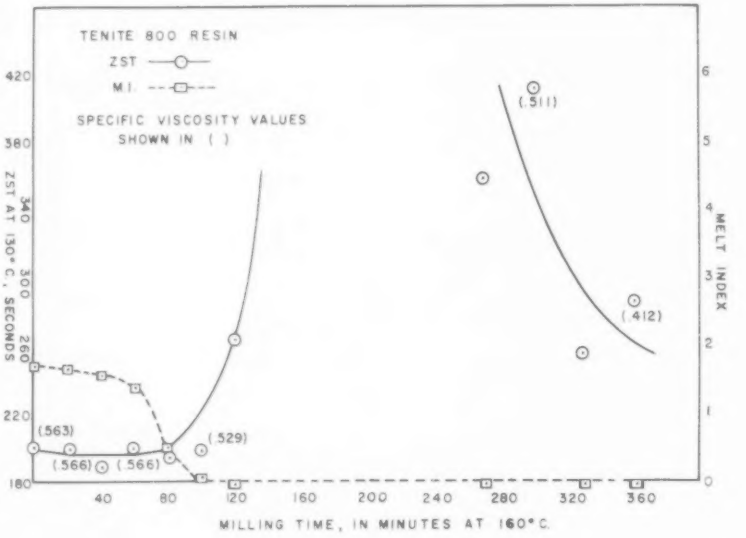


through 12 were obtained. Melt index values and specific viscosity data were also secured for these oxidized polyethylene specimens (*6*).

Applicability of the ZST Test

As had previously been stated, the ZST and melt index values obtained for the various incrementally oxidized polyethylene resins form a pattern of rise and fall which accords with the cross linking and chain scission reactions known to accompany polymeric oxidative degradations. It seems reasonable to assume the implied causality, and to conclude, therefore, that ZST, like melt index, mirrors the course of polyethylene degradation. *Figure 3*, representing the results for air oxidized DYNF resin, shows that the changes accompanying progressive oxidation are more significantly reflected by ZST than they are by melt index. Interestingly, the indicated specific viscosity values for these resins also show the same general pattern of cross linking followed by chain scission. However, the peak points for maximum cross linking as measured by ZST and specific viscosity are displaced. The ZST measurement is seen to be the more sensitive of the two.

Figure 5. Variation of ZST & melt index with extent of air oxidation of Tenite 800



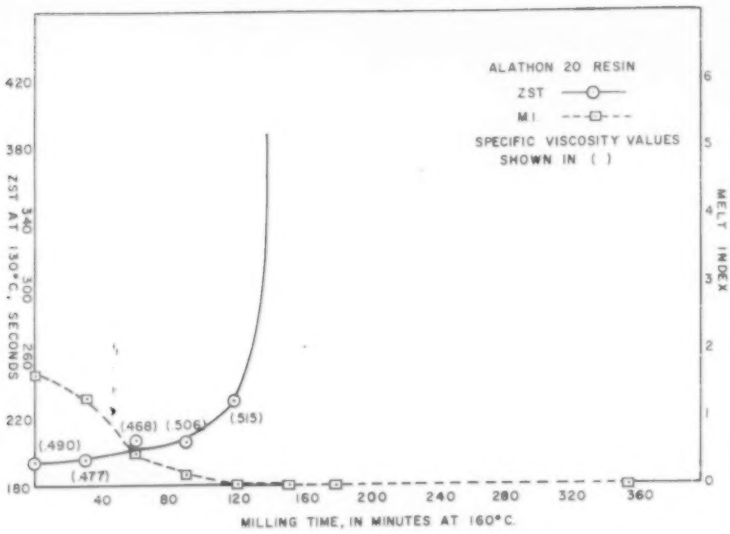


Figure 6. Variation of ZST & melt index with extent of air oxidation of Alathon 20

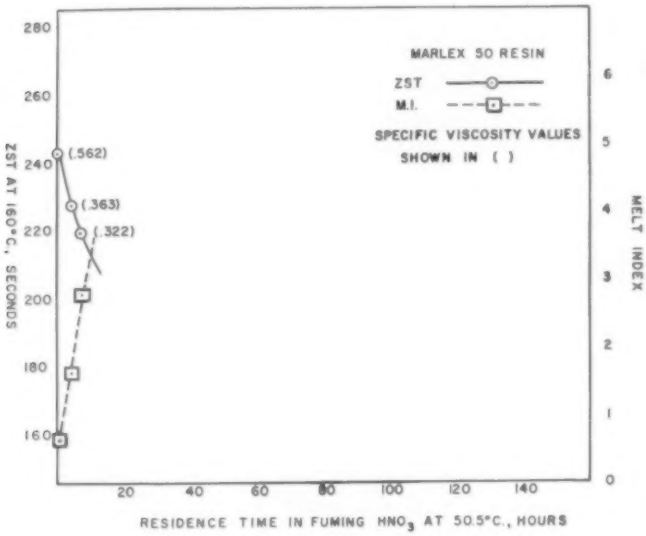


Figure 7. Variation of ZST & melt index with extent of oxidation of Marlex 50

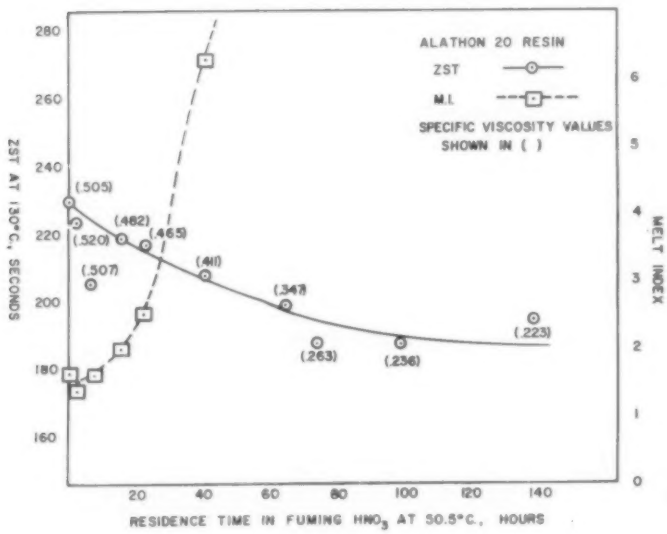


Figure 8. Variation of ZST & melt index with extent of oxidation of Alathon 20

While generally covering a more extensive span of resin degradation than melt index, ZST is not without its limitations. Thus *Figure 4* shows that certain degrees of oxidation imposed upon Alathon 10 resin by hot milling can not be represented by ZST values, as these become too large to measure accurately. However, melt index is even less sensitive, and more restricted in its application.

Even sharper limitations are placed upon the utility of the ZST test in following the air oxidation of Eastman Chemical polyethylene Tenite 800 and Alathon 20. This is shown in *Figures 5 and 6* respectively which also indicate the superiority of ZST over melt index in those regions where either measurement can be made. Despite these limitations, ZST is suitable for assessing polyethylene degradation, especially the initial oxidation reaction.

Figure 7 shows that the effect of the vigorous oxidative action of fuming nitric acid on Phillips Chemical Co. polyethylene Marlex 50 resin can be measured only for short exposure times. Interestingly, no indication of cross linking is given by either melt index or ZST for Marlex 50 oxidized by fuming nitric acid.

In distinction to that of the Phillips resin, the fuming nitric acid oxidation of the Dupont polyethylene Alathon 20 can be followed over most of its course by ZST measurements. This is shown in *Figure 8*. In this instance, as in the case of Alathon 10 and DYNF, represented by *Figures 9 and 10* respectively, ZST is seen to be superior to melt index as an assay tool for oxidative degradation. Again, the fuming nitric acid oxidation, perhaps as a consequence of its severity,

shows no sign of a cross linking reaction, but goes immediately to chain scission. This phenomenon is corroborated by the specific viscosity values of these oxidized resin samples.

DMDA, Bakelite linear resin, shows the pecularity of the Phillips resin in that its fuming nitric acid oxidation can be followed to a lesser extent by either melt index or ZST than can that of the conventional polyethylenes examined. This is seen in *Figure 11*.

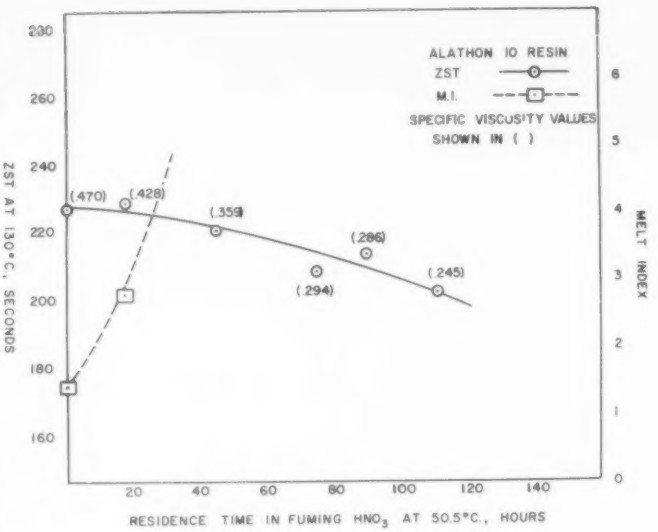


Figure 9. Variation of ZST & melt index with extent of oxidation of Alathon 10

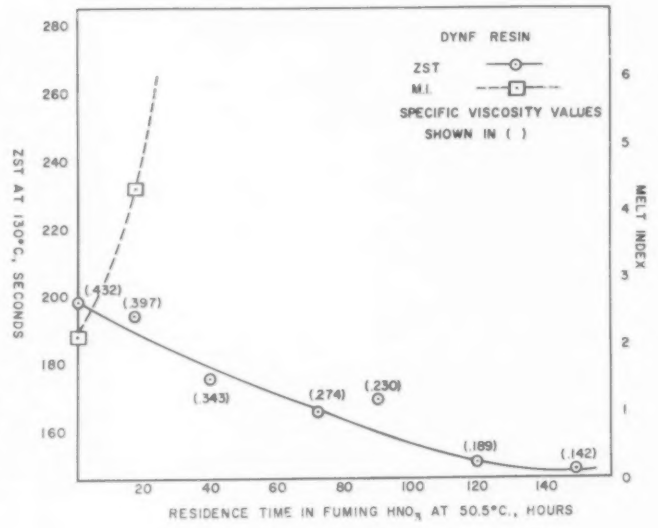


Figure 10. Variation of ZST & melt index with extent of oxidation of DYNF resin

It is known that polyethylene resins may differ significantly in molecular structure. Not surprisingly, therefore, they may vary widely in their behavior toward a common reactant. Thus *Figures 12 and 13*, representing DYND and Eastman Chemical subject polyethylene respectively, show a wide disparity in response to fuming nitric acid oxidation. In particular, the data for the Eastman polyethylene show the occurrence of cross linking. *Figure 13* illustrates the appropriateness of the ZST test for measuring a wide extent of polymeric degradation.

ZST and Melt Index

A thermocouple was inserted into a ZST test specimen and the temperature rise was recorded as a function of time. The results, presented in *Table 4*, show that about 80 seconds were required for the plastic strip to reach 100°C, taken as the point above which polyethylene crystallinity probably no longer exists. The furnace was maintained at 130°C. Also listed in Table 4 is the rate of temperature rise for a 160°C furnace. In this case 100°C was reached after 40 seconds. Assuming an overall ZST value of 240 seconds, it is seen that one third of this time involves the solid state property of

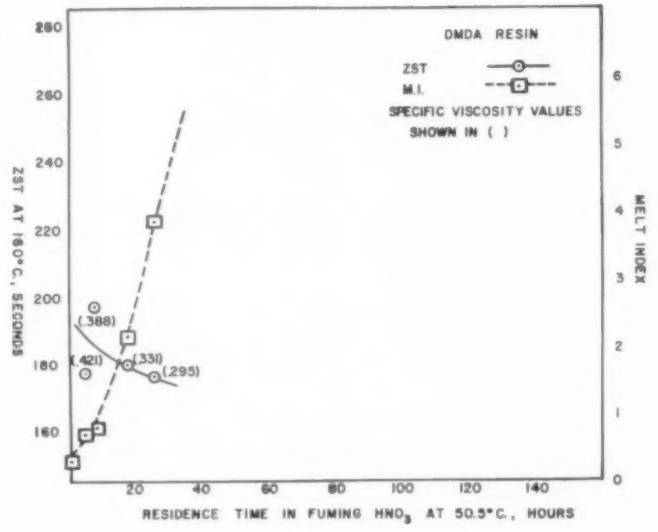


Figure 11. Variation of ZST & melt index with extent of oxidation of DMDA resin

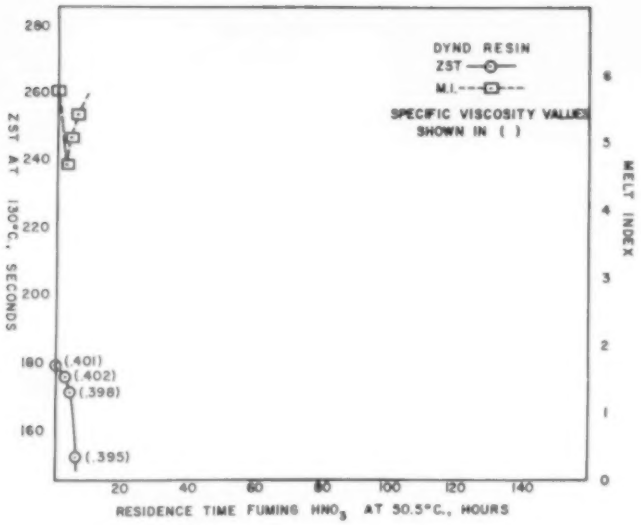


Figure 12. Variation of ZST & melt index with extent of oxidation of DYND resin

crystallinity for the polyethylene tested. This is the chief point of distinction between the ZST test and melt index. In the latter test, the plastic is well above its crystallinity point before its flow measurement is made. For this reason ZST and melt index curves for oxidized plastics are not superimposable.

The effect of density, an index of polyethylene crystallinity, upon ZST now becomes apparent. This is shown in *Figure 14* (5). Molecular weight and ZST do tend to exhibit a direct relationship, for molecular complexity influences ZST values. However, crystallinity is also important in determining a polyethylene's ZST value, and modifies the direct relationship of melt index, a rough index of molecular size, and ZST.

Table 4. Rate of Temperature Rise of Sample

Furnace Temperature 130°C.		Furnace Temperature 160°C.	
Temperature	Time	Temperature	Time
65°C	20 sec.	83°C	20 sec.
81	40	107	40
93	60	121	60
99	80	128	80
103	100	133	100
106	120	134	120
108	140	136	140
110	160	138	160
113	180	141	180
117	200	148	200
119	220	153	220
121	240		
123	260		
125	280		

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Acknowledgment

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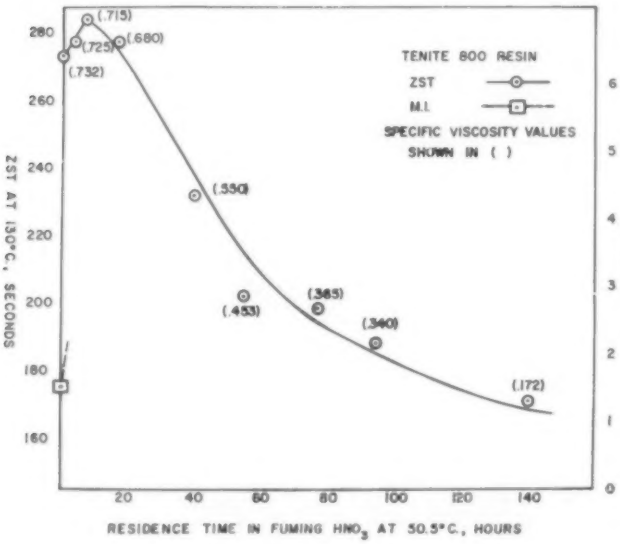


Figure 13. Variation of ZST & melt index with extent of oxidation of Tenite 800

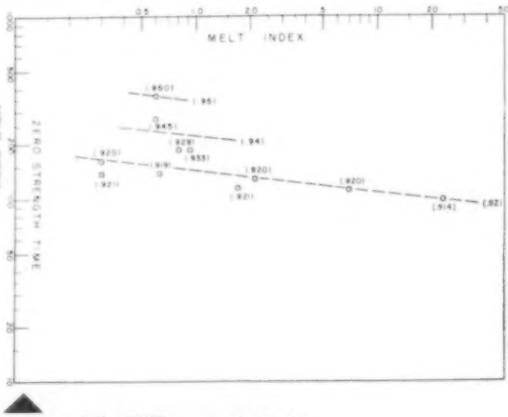


Figure 14. ZST vs melt index

Relations Between Physical Properties And Molecular Structure of Polypropylenes

This article provides a series of curves, useful as references, for relating physical properties of polypropylenes to variations in their molecular structure

N. H. Shearer, Jr., J. E. Guillet, and H. W. Coover, Jr.
Research Laboratories, Tennessee Eastman Company
Division of Eastman Kodak Company

Considering the polyolefin field in general, including the crystalline polymers of ethylene, propylene, and the higher olefins, it is now possible to produce many widely varying types of polyolefins having physical properties which range from those represented by the rubbers to those found in the high-softening, highly crystalline polyamides and polyesters. In view of the low cost of the olefins, it is important from the economic as well as the academic standpoint to determine the effects of the molecular structure parameters upon the physical properties of the polyolefin family.

The following are considered to be the important molecular structure parameters governing the physical properties of all the polyolefins: average molecular weight, distribution of molecular weight, average degree of branching, distribution of branching, average degree of stereoregularity, and distribution of stereoregularity. This article concerns the variation of molecular weight, amorphous content and branching in a group of polypropylenes and the resultant effect upon such physical and mechanical properties as density, hardness, stiffness, tensile modulus, heat-distortion temperature, tensile yield strength, elongation, tensile break strength, and Izod impact strength.

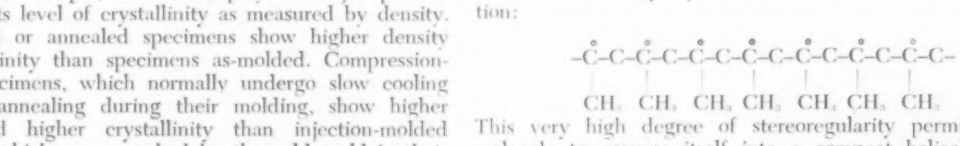
Structural Considerations

The levels attainable in each of the above properties will materially affect the type of applications which any given polypropylene sample could fill. The thermal history of a polypropylene sample, of course, plays a major part in governing its level of crystallinity as measured by density. Conditioned or annealed specimens show higher density and crystallinity than specimens as-molded. Compression-molded specimens, which normally undergo slow cooling and some annealing during their molding, show higher density and higher crystallinity than injection-molded specimens, which are quenched by the cold mold in their normal course of molding. Compression-molding can, therefore, be expected to maximize those properties associated principally with crystallinity; namely, density, hardness, stiffness, tensile modulus, heat-distortion temperature, and tensile yield strength. Injection-molding, by means of its orienting effect, can be expected to maximize those properties principally governed by molecular weight; that is, elongation, tensile break strength, and impact strength.

In the case of polyethylene, the molecular structure parameters which have been examined are: molecular weight, distribution of molecular weights, short-chain branching, long-chain branching, and distribution of branching.

With polypropylene, all of these, plus the additional parameters of stereoregularity and the distribution of stereoregularity, must be taken into account. The polypropylene molecule has a methyl group attached to every other carbon atom in its chain, whereas polyethylene molecules have relatively few side chains per hundred carbon atoms, the number being determined by the degree of branching in that particular polyethylene molecule.

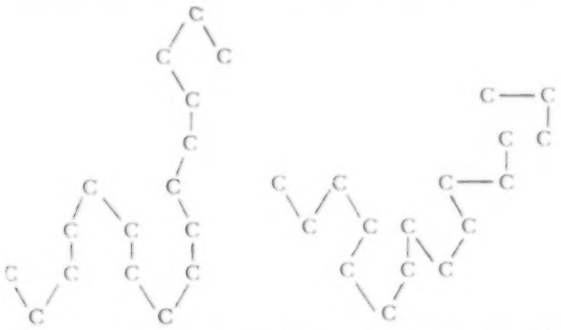
Since every other carbon atom in a polypropylene molecule possesses an asymmetric center, the stereoregularity of the molecule as a whole and the distribution of stereoregularity become extremely important. It is possible to have a molecule where each asymmetric carbon has the same configuration as its neighbors; for example, a molecule in which every asymmetric center has a "d" configuration:



This very high degree of stereoregularity permits each molecule to arrange itself into a compact helical chain.

Each of these chains can pack very closely with neighboring chains during the cooling and crystallization. This leads to high densities and to highly crystalline behavior.

The high degree of stereoregularity illustrated here can be diminished in at least two ways. First, the asymmetric centers can possess a random distribution of "d" and "l" configurations, which lead to irregularly shaped molecules:



These are the type obtained from the action of acidic catalysts upon propylene. They cannot pack closely upon cooling and therefore the polymer has a low density and shows those properties associated with a low degree of crystallinity. Second, reduced stereoregularity can arise from stereoblock polymers which have within the molecule an occasional interruption in stereoregularity; that is, the occurrence of a center of "l" configuration at various intervals among the centers of "d" configuration. The possibility also exists for segments of high stereoregularity to be interrupted by short segments having random configurations. Molecules of intermediate stereoregularity can be expected to show medium density and intermediate crystallinity.

In 1953, Sperati, Franta, and Starkweather, of Du Pont, described the effect of chain branching and molecular weight on the physical properties of low- and medium-density polyethylenes.(1) They found that chain branching, which was mostly of the short variety, is the major factor in controlling density and crystallinity. Thermal history and molecular weight are of less importance to crystallinity.

Stiffness was found to be dependent upon crystallinity as measured by density. At constant density, stiffness was independent of molecular weight (melt viscosity). A quenched polyethylene sample had a lower density and corresponding lower stiffness than a sample which had been cooled slowly, but the difference between the two is small when compared with the total range represented by the branching parameter. It was found with polyethylene that branching need not be even in all the chains but that average branching is the effective factor in controlling density, stiffness, and yield point. A blend of 55% of a 0.914 density polyethylene with 45% of a 0.940 density polyethylene showed the predicted intermediate values for density, stiffness, and yield point.

Yield strength was found to be dependent upon crystallinity; the lowest molecular weight sample was too brittle to provide yield values. Break strength was found to be dependent primarily on molecular weight.

Elongation was found to be dependent upon both density and molecular weight. Here the rate of elongation is an important factor. Slow rates of elongation in highly crystalline polymers permit cold drawing and lead to high values for percentage elongation.

Vicat softening temperature and hardness were found to be dependent upon both density and molecular weight. Density was found to be the more important factor in each case. Molecular weight played a stronger role in Vicat softening temperature than in hardness. A high-molecular-weight polyethylene of 0.910 density, for example, showed

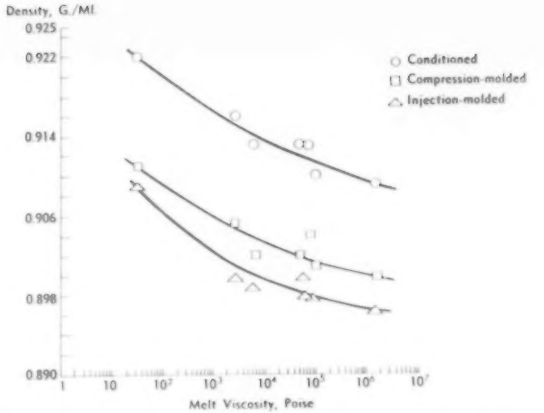


Figure 1. Variation in density with molecular weight.

a Vicat softening point equivalent to that in a low-molecular-weight polyethylene having a much higher density of 0.925. The high-molecular-weight polyethylene of 0.910 density, however, showed slightly lower hardness than the low-molecular-weight polyethylene of 0.925 density, indicating molecular weight to be less important in governing the hardness than in governing the softening temperature.

In 1957, Burch, Field, McTigue, and Spurlin, of Hercules, reported a similar study on medium- and high-density polyethylenes.(2) They looked at three different kinds of polyethylenes: high-linearity with narrow molecular weight distribution, high-linearity with broad molecular weight distribution, intermediate-linearity with intermediate molecular weight distribution. They concluded that narrow distribution in polyethylene leads to lower crystallinity, lower hardness, higher impact strength, and higher elongation. Wide distribution in polyethylene leads to high crystallinity, high hardness, and high stiffness. Intermediate-linearity in polyethylene showed lower crystallinity, lower hardness, and lower stiffness than the highly linear samples.

The polypropylene samples used in the present study included samples of highly crystalline polypropylenes ranging from rather low to high average molecular weight, as determined by both melt viscosity and inherent viscosity and samples made by blending on heated rolls highly crystalline polypropylene with amorphous polypropylene having a 0.861 density. A variation in branching was accomplished by copolymerizing propylene with 1-hexene.

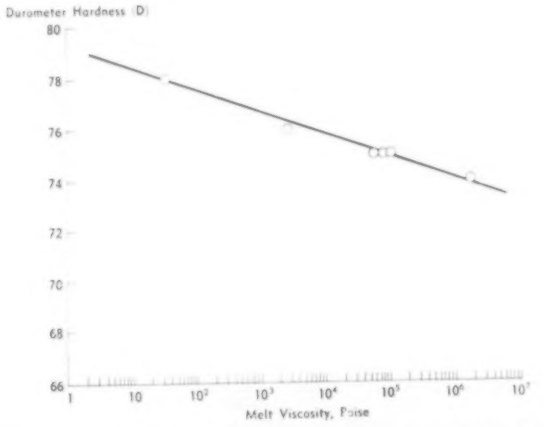


Figure 2. Variation in hardness with molecular weight.

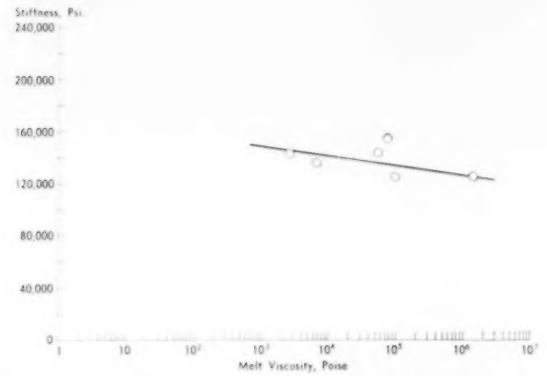


Figure 3. Variation in stiffness with molecular weight.

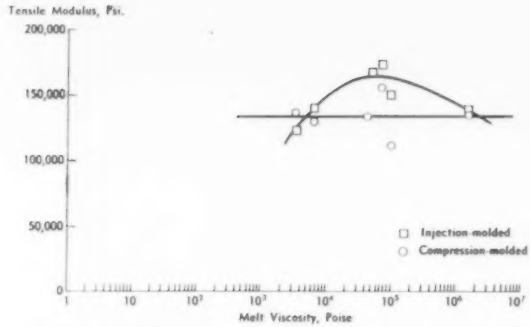


Figure 4. Variation in tensile modulus with molecular weight.

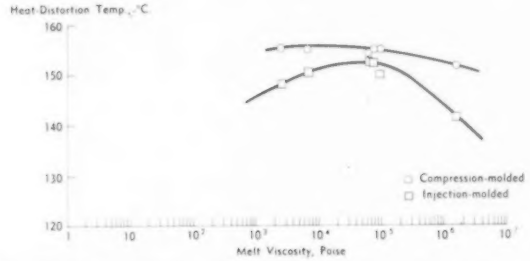


Figure 5. Variation in heat-distortion temperature with molecular weight.

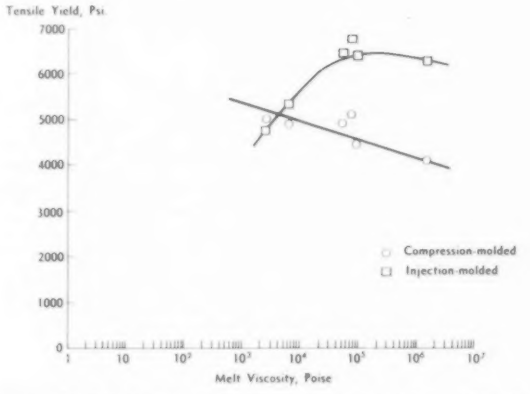


Figure 6. Variation in tensile yield with molecular weight.

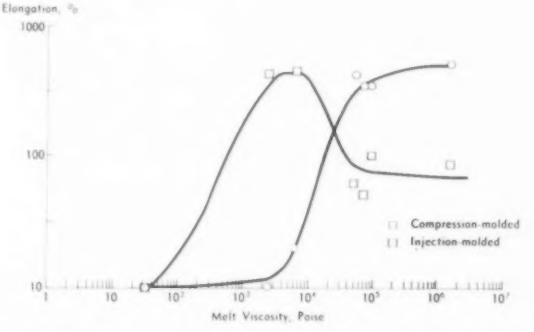


Figure 7. Variation in elongation with molecular weight.

The Effect of Molecular Weight

The measurement of absolute molecular weights for polypropylene is difficult. In the discussion to follow, the melt viscosity at 230°C. has been used to indicate the relative degree of polymerization. This is convenient, since it also gives an indication of the ease with which the polymer may be fabricated and therefore has a practical meaning to the plastics producer or fabricator. The melt viscosities were determined in a conventional Slocomb melt indexer under Condition I of ASTM Procedure 1238-57T by application of Poiseuille's law. The viscosities so determined are really "apparent melt viscosities", not independent of the shear rate at which they were determined.

Density. *Figure 1* shows density as a function of molecular weight for compression- and injection-molded samples of polypropylenes having high stereoregularity. The top curve represents compression-molded samples after conditioning. In all three cases, the density decreases regularly with increasing molecular weight. The relative position of each curve is as expected, in view of the thermal history of the samples. The smaller molecules with a greater number of chain ends per unit volume can move rather freely into positions favorable to maximum crystallization, whereas the larger molecules become entangled more easily, leaving more extensive amorphous zones separating the crystalline regions. For the lowest molecular weight polypropylene the densities of the compression- and injection-molded specimens are closer together than in the case of higher molecular weight specimens. Apparently, for the smaller molecules, differences in molding conditions have less effect.

Hardness. *Figure 2* shows a linear decrease in hardness with increasing molecular weight.

Stiffness. The decrease in stiffness with increasing molecular weight is shown in *Figure 3*. The lowest in the molecular weight series was too brittle to provide a stiffness value. The very gradual slope here indicates that the larger molecules contribute to stiffness in excess of that expected from the crystallinity as measured by density.

Tensile Modulus. *Figure 4* shows a constant value for tensile modulus over the entire molecular weight range for compression-molded specimens. A slight maximum, yet unexplained, can be observed at intermediate molecular weights in injection-molded specimens. This hump was not observed in stiffness measurements, where the injection-molded specimens showed a gradual decrease with increasing molecular weight at a level about 30,000 psi. lower than compression-molded specimens.

Heat-Distortion Temperature. Molecular weight has little effect on the heat-distortion temperature of compression-molded samples, as seen in *Figure 5*; a slight decrease can be observed at the highest molecular weight value. Once

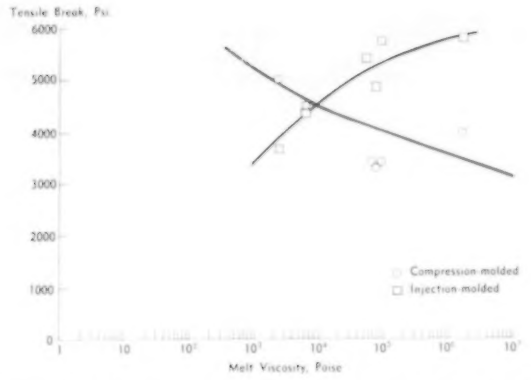


Figure 8. Variation in tensile break with molecular weight.

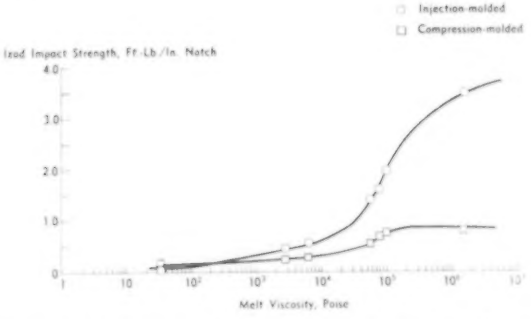


Figure 9. Variation in izod impact strength with molecular weight.

again a peak near the intermediate-molecular-weight specimens, similar to that noted with tensile modulus, can be seen in the injection-molded samples. Here the injection-molded specimens show lower heat-distortion temperature than compression-molded specimens, probably reflecting the release of strains induced during molding.

Tensile Yield. In *Figure 6*, the tensile yield of compression-molded samples is shown to decrease slightly with increasing molecular weight, in line with density values previously observed. The tensile yield values for injection-

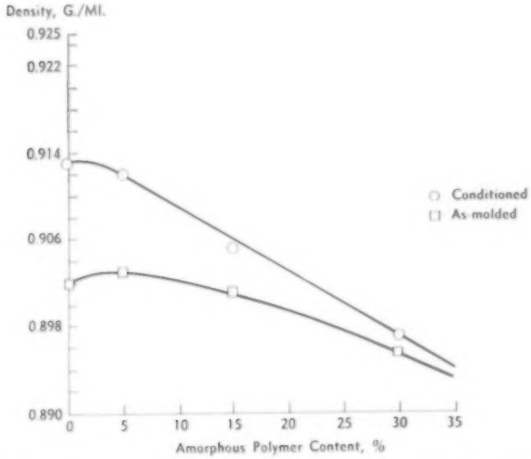


Figure 10. Variation in density with amorphous polymer content. (compression-molded specimen)

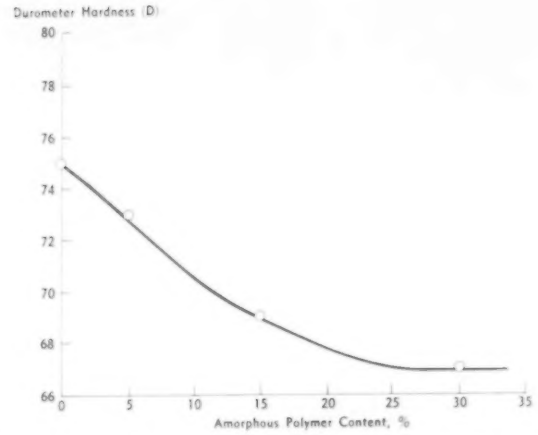


Figure 11. Variation in hardness with amorphous polymer content. (compression-molded specimen)

molded specimens actually increase slightly with an increase in molecular weight.

Elongation. The rapid increase in elongation with increasing molecular weight is illustrated in *Figure 7*. The orienting effect of injection-molding causes these specimens to show the molecular weight response at a considerably lower molecular weight level than do the compression-molded samples. The very high molecular weight injection-molded specimens are already so highly oriented during the molding process that very little elongation is possible. High tensile yield and high tensile break strengths characterize these specimens. Higher molecular weight compression-molded samples, largely unoriented as-molded, can undergo extensive elongation during the tensile testing.

Tensile Break Strength. In *Figure 8*, the tensile break strengths are shown for compression- and injection-molded specimens. In general, these samples show break strengths lower than their tensile yield strengths. In both types the tensile break values are slightly lower than tensile yield values with one exception: the lowest molecular weight specimen in the compression-molded series. For this sample, tensile break and tensile yield values are the same, and the elongation value, as you will recall from *Figure 7*, was quite low. An injection-molded specimen of the same molecular weight gave a tensile yield value of 4,800 psi., an elongation of 450%, and then broke at 3,700 psi.

Izod Impact Strength. The Izod impact strength was found to increase materially with molecular weight, as seen in *Figure 9*. Here again the orienting effect of injection-molding is strikingly illustrated. Increasing molecular weight beyond 10^5 poise has little effect on the Izod impact strength of compression-molded specimens, but has a pronounced effect on injection-molded specimens.

Effects of Mixing Amorphous and Crystalline Polypropylenes

As Natta has indicated, various types of crystalline polypropylene can be made by suitable alteration in the polymerization conditions. The following is a study of the effects of varying the amounts of amorphous polymer blended with a crystalline polymer having a density of 0.913.

Density. A plot of the variation in density with stereoregularity, as controlled by amorphous polymer content, is shown in *Figure 10*. Densities are shown for compression-molded specimens as-molded and after being conditioned by slowly cooling from 160°C. in a vacuum oven.

Thermal History. It is interesting to note that the presence of 5% amorphous polymer in the blend promotes crystallization and leads to a higher as-molded density than

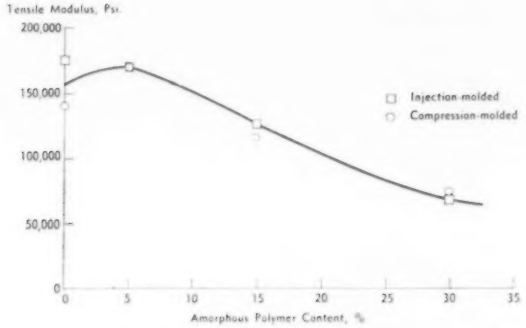


Figure 12. Variation in stiffness with amorphous polymer content.

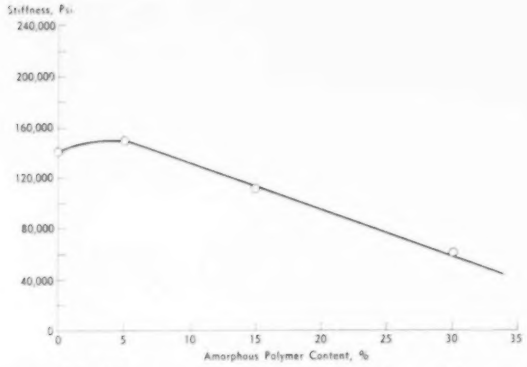


Figure 13. Variation in tensile modulus with amorphous polymer content.

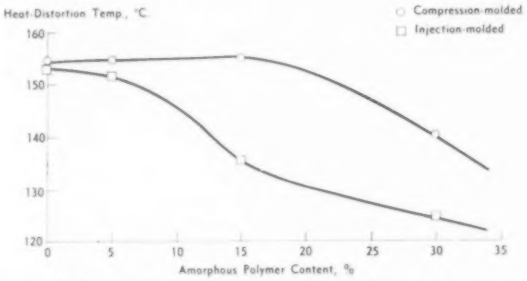


Figure 14. Variation in heat-distortion temperature with amorphous polymer content.

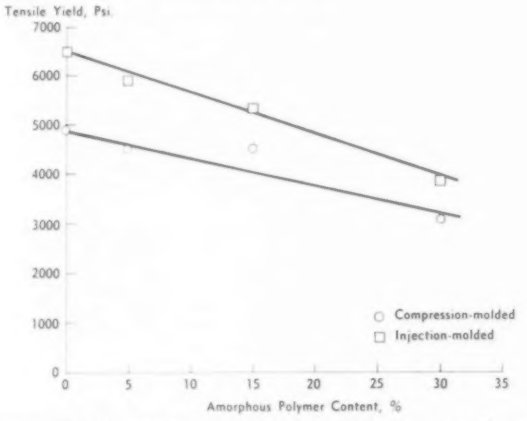


Figure 15. Variation in tensile yield with amorphous polymer content.

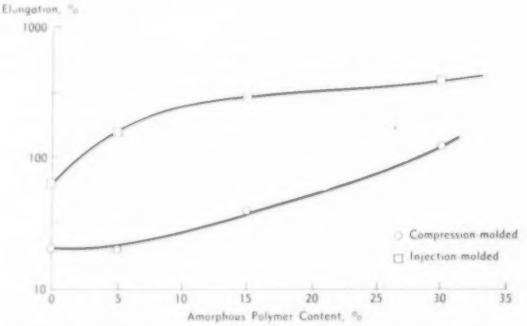


Figure 16. Variation in elongation with amorphous polymer content.

with none present. After being conditioned, however, the maximum density obtainable is slightly less with 5% amorphous polymer present than with none. This plasticizing effect is even more pronounced in the blends having 15% and 30% amorphous content. At 30% amorphous polymer content the as-molded density is only slightly lower (0.895) than the conditioned density (0.897), in contrast to the wide difference, 0.902 and 0.913, in the highly crystalline specimens. Theoretically, the amorphous polymer can be considered to be acting as a plasticizer, facilitating molecular movement of crystallizable polymer chains into favorable positions for formation of crystalline areas. Such plasticization promotes crystallization at temperature below those normally required for annealing.

The reduction in density with amorphous polymer content is virtually linear for conditioned samples, but departs significantly from linearity in the as-molded specimens. Thus objects molded from amorphous blends should show a slightly higher level in those physical properties associated with density and crystallinity than one would expect from their percentage composition. It should be pointed out that this entire density range is considerably lower than that attainable in highly crystalline polypropylene.

Hardness. *Figure 11* shows the decrease in Durometer hardness (D scale) with the increase in amorphous polymer content. It is more pronounced than one would expect from the density differences observed earlier. The rapid drop in hardness which occurs from 0-15% amorphous polymer content becomes more gradual at 15-30%.

Stiffness. The effect of amorphous polymer content on stiffness is shown in *Figure 12*. Variation from linearity is in agreement with the change in densities observed earlier in amorphous blends.

Tensile Modulus. The tensile modulus, or slope of the initial portion of the stress-strain curve, provides another and perhaps more accurate measure of stiffness. The effect of amorphous polymer content on tensile modulus is the same as that observed in the stiffness in flexure measurement. This is shown in *Figure 13*. Virtually the same modulus values were obtained for both compression-molded and injection-molded specimens.

Heat-Distortion Temperature. A most interesting difference in the heat-distortion temperatures of compression-molded as compared with injection-molded specimens is seen in *Figure 14*. The injection-molded values follow the pattern expected from the density measurements, whereas the compression-molded samples, particularly the one having 15% amorphous content, show unexpectedly high values for heat-distortion temperature. Lower values for injection-molded specimens may be due to the release of strains generated during the molding.

Tensile Yield. In *Figure 15*, the linear decrease in tensile yield with an increase in amorphous polymer content

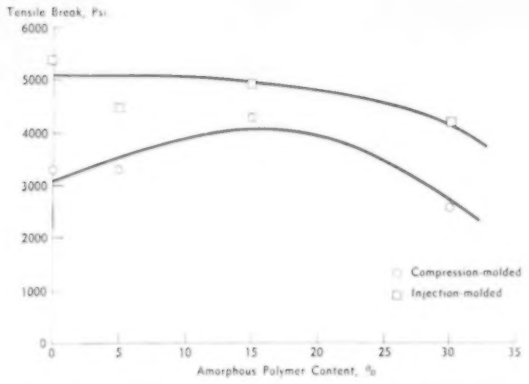


Figure 17. Variation in tensile break with amorphous polymer content.

shown is in agreement with observed decreases in crystallinity as measured by density. This time, however, the orienting effect of injection-molding serves to increase the tensile yield of injection-molded specimens beyond that of the compression-molded specimens.

Elongation, Tensile Break Strength, and Izod Impact Strength of Partially Amorphous Samples. An increase in elongation with increasing amorphous content is shown in *Figure 16*. The oriented injection molded samples here again show higher values than corresponding compression-molded samples. *Figure 17* shows the superiority once again of the oriented specimens in tensile break strength. Since tensile yield decreases linearly with increasing amorphous content while percentage elongation increases. The nearly flat curves for tensile break reflect a relative gain in strength at the 15-30% amorphous content level as a result of orientation during the tensile test. The Izod impact strength is shown in *Figure 18* to increase linearly with an increase in amorphous polymer content and in line with decreasing crystallinity.

The Effect of Branching

The effect of adding some branches similar in length to those found in lower density polyethylenes is shown in *Table 1*. The hexene copolymer contains about 5% 1-hexene and has far lower values for density, hardness, stiffness, tensile modulus, tensile yield, and heat-distortion temperature.

Summary

The effects of molecular weight, amorphous content, and branching upon polypropylene physical properties are summarized.

(1) Density decreases rapidly with increasing molecular weight, decreases gradually with increasing amorphous content, and decreases rapidly with increased branching.

(2) Hardness decreases gradually with increasing molecular weight and decreases rapidly with increasing amorphous content and with increased branching. Stiffness also decreases gradually with increasing molecular weight, decreases rapidly beyond 5% with increasing amorphous content, and decreases rapidly with increased branching.

(3) Tensile modulus and heat-distortion temperature remain relatively constant with increased molecular weight but decrease rapidly with increased amorphous content and increased branching.

(4) Tensile yield increases with increasing molecular weight in injection-molded specimens but decreases in compression-molded specimens. It decreased steadily with increasing amorphous content and rapidly with branching.

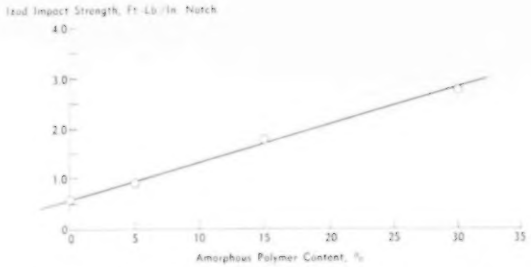


Figure 18. Variation in izod impact strength with amorphous polymer content. (compression-molded specimen)

(5) Elongation shows a maximum at intermediate molecular weight in injection-molded specimens and increases with increasing molecular weight in compression-molded specimens. Elongation increases steadily with increasing amorphous content and rapidly with increased branching.

(6) Tensile break increases with increasing molecular weight in injection-molded specimens and decreases in compression-molded specimens. Tensile break decreases gradually with increasing amorphous content and remains relatively constant with increased branching up to 5%.

(7) Izod impact strength increases with increasing molecular weight, the effect being most pronounced in injection-molded specimens. It increased steadily with increased amorphous content and rapidly with increased branching.

This study has provided a useful set of reference curves relating the physical properties of different polypropylenes to the variation in their molecular structure. These findings should be widely applicable to polyolefins in general.

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1. C. A. Sperati, W. A. Franta, and H. W. Starkweather, Jr., *J. Am. Chem. Soc.*, 75, 6127 (1953).
2. G. N. B. Burch, G. B. Field, F. H. McTigue, and H. M. Spurlin, *SPE Journal*, 13 (No. 5), 34 (1957).

Table 1. Effect of Branching on Physical Properties of Polyolefins

	Polypropylene	Copolymer of Propylene and 1-Hexene
Inherent viscosity	1.86	1.66
Melt flow (230°C.)	2.56	4.28
Melt viscosity (230°C.), poise	54,000	32,200
Density (conditioned) g./ml.	0.913	0.893
(as-molded), g./ml.	0.902	0.893
Durometer hardness (D)	75	65
Stiffness, psi.	144,000	43,000
Tensile modulus, psi.	137,000	46,000
Impact strength (Izod), ft.-lb./in. notch	0.53	9.7
Elongation, %	440	570
Tensile strength at yield, psi.	4,800	2,300
at break, psi.	3,400	3,400
Heat-distortion temp., °C.	154	115

Molding with Plastisols

This article describes slush and rotational molding of Poly(vinyl chloride) articles. Included is a description of the process, and formulations and manufacturing procedures

Howard G. Nadell
Irwin L. Podell, Inc.

Basically, slush molding involves filling a mold with the material in question (a liquid), emptying the mold (hence the term slush) and fusing, cooling or curing the skin which is left behind in the emptied mold. For plastisols, the application and the term to be used is fusion. There are many variations of the slush molding technique used to arrive at this fused state. The mold may be preheated, so that a heavier or thicker skin (the result of gelation at the heated surface) is deposited for fusion. The mold may be heated after it is charged with plastisol and then emptied, for much the same purpose. In some cases a double slush process may be employed whereby the first slush is emptied and gelled and then another slush is added, emptied and the total fused. The mold may be spun while it is filled with plastisol to fill out specific areas. Combinations of these and other techniques may also be employed.

Double Slush Molding

Take for an example a large slushed doll body and the technique used for its manufacture. Although the detail involved in the body features is not unusual, the length of the body and the narrow wrists and ankles, as well as thin fingers, necessitates certain properties in the plastisol formulation. First, the plastisol must be low in viscosity; it must have good flow properties to fill the finger areas; and it must be rigid enough so that a minimum quantity of stuffing will allow it to stand without distortion, yet not so rigid that it cannot be stuffed. Air release properties must be very good to avoid the appearance of bubbles at the skin surface, and viscosity stability must be good to avoid unusual viscosity buildup as a result of the heat—slush cycle. A double slush technique is used for this particular item. The general formulation is as follows:

1st slush *(parts by weight)*		2nd slush *(parts by weight)*
100	Paste resin	100
55	Butyl decyl phthalate	35
10	Secondary plasticizer	10
5	Ester-type epoxy plasticizer	3
2	Ba-Cd-Zn liquid stabilizer	2
4	Pigment	4
	Filler	10
	Polyethylene glycol 400 ML	2
	Odorless mineral spirits	2-3

The technique used for molding this particular body is described next. A copper mold, the interior of which has been plated, is charged with the first slush plastisol, after which the mold is emptied and allowed to drain until the flow-out has sufficiently ceased. The mold is then inverted and submerged in hot water at a predetermined temperature and time cycle, so that this initial slush is gelled upon removal from the bath. The mold is filled again, this time with the second slush plastisol, and the filled mold is then submerged in hot water at a temperature and for a time cycle determined by the desired thickness of the skin. After being transferred from the bath, water clinging to the exterior of the mold is removed by forced air, and the mold drained. In this drain position the mold passes before a

series of infrared heat lamps, to harden the soft plastisol gel, thereby preventing sag and excessive drip in the oven. From here the mold passes into the oven where the skin is cured. After cure and a quench in cool water, the skin is removed using a vacuum stripper, which is nothing more than a perforated pipe around which the neck of the doll body is tightly wrapped. The resulting suction causes the skin to pull away from the mold walls while it is being removed.

A few comments should be made at this point regarding technique. Objectives of the first slush are as follows: (a) to provide a thin, bubble free outer skin, (b) to provide a filler-free outer skin and thereby avoid the possibilities of surface scratching, (c) to utilize the properties of a low viscosity plastisol to fill in any necessary detail which could not be done with a higher viscosity second slush, and (d) to provide a surface feel or texture which could not be duplicated by a more rigid material. Although the first slush plastisol is constantly reused after each slush, it is never heated, and so its viscosity, stability and flow properties, if properly compounded, are usually quite excellent.

The second slush has the advantage of being able to use a quantity of filler which has a reasonable effect upon compound cost. It is the more rigid of the two materials and is present in the greatest proportion in the finished skin. Considerable effort is taken to keep the viscosity of this material from reaching unworkable proportions. The formulation contains PEG 400 ML to help keep the viscosity low; liquid barium-cadmium-zinc stabilizer systems are chosen for their beneficial effects upon viscosity buildup and air release. In addition, odorless mineral spirits are used in judicious quantity to lower viscosity, and specifically, because of their high boiling point to negate loss from the system and to reduce blistering and fire hazard. During the cycle, the tank from which the plastisol is pumped is constantly supplied with fresh material to keep temperature and viscosity at the lowest possible level.

Single Slush Molding

There have been cases where this double slush technique has been found impractical because of existing or available equipment. In these cases, plastisol items are single slushed and various techniques are employed to avoid or negate surface imperfections and to arrive at a compound-surface-cost-rigidity compromise which is satisfactory.

In a typical single-slush mold application, the mold is mounted about its vertical axis. When filled, it is placed in a spinning device so that the spin takes place about this axis. This method has several distinct advantages as opposed to the double slush method: (a) Centrifugal force produced by the spin forces air to the surface and breaks these air bubbles at the plastisol-mold interface; (b) centrifugal force also forces the plastisol into the finest detail of the mold allowing for excellent detail reproduction; and (c) plastisol viscosity does not play quite so important a role with this technique because fairly heavy plastisols can be readily spun into fine areas. The disadvantages lie in surface texture and amount of filler which can be used in the plastisol. In many cases, the manufacturer is unable to use any filler unless surface scratch or mar is not a major consideration. Of great importance also is the fact that this technique permits handling of only one or two molds at a time, with the subsequent effect upon production rate.

Rotational Molding

Rotational molding differs from slush molding in equipment application to a greater extent than in plastisol compounding. In fact, there is very little to prevent a slush molding compound from being used with rotational molding equipment.

In rotational molding, a predetermined weight of plastisol (depending upon the desired weight of the object to be molded) is charged into a plated copper or aluminum mold. After sealing, the mold is rotated about *two* axes in such a manner that the plastisol is caused to flow over the entire inner surface of the mold. During this rotation, heat is applied to the exterior of the mold causing gelation of the plastisol along the interior walls of the mold and forming a gelled skin. This skin is subsequently fused, the mold cooled, and opened, and the molded item removed. The formulation for a rigid plastisol item (a ball) is as follows:

Paste resin	100
Butyl decyl phthalate	20
Secondary plasticizer	5
Dioctyl adipate	5
Ester-type epoxy plasticizer	5
Ba-Cd liquid stabilizer	2.5
Silicone oil	0.1

The technique used for molding the ball utilizes steam gel and gas fusion. After charging with plastisol, the mold is rotated in an enclosed chamber and subjected to direct live-steam heat. Pressure and temperature of the steam determine the heat-time cycle which, with good steam generation, is usually no more than 1½-2 minutes. The mold then passes into an oven, where the plastisol is fused. During this time the rotary motion is continued to avoid "pockets" caused by plastisol which has not completely gelled and to present greater surface uniformity for heating. The mold can then be chilled with air or water, using for example, a shower spray device, and depending upon time cycle and equipment. The mold is stripped, i.e., the ball is removed while it is still warm. This prevents the plastisol from becoming so rigid that it either cannot be removed or distorts or tears upon removal. The mold is then filled and recycled.

Formulation for this article again involves liquid stabilizers because of the desire for low viscosity and better flow. Because of the low level of plasticizer, silicone oil is used to decrease viscosity and surface tension and to impart better flow to the plastisol. Small amounts of solvent can be used, but with caution. Ester-type epoxy plasticizers are used again for low viscosity and improved flow purposes.

Rotational speeds employed to revolve the mold about the axis are of the utmost importance and represent the difference between successful molding and failure. The rate of rpm's encountered by the mold determine to a great extent the buildup of the plastisol in a specific area. As with the spun-slush molded items, revolutions can throw plastisol to an area with either desirable or undesirable results. Molding of unsymmetrical objects takes great advantage of this rpm factor, both in the manner of mold mounting and the speeds obtained during the cycle. Elongated objects, for example, are usually mounted close to their centers and rotated slowly so that the plastisol has time and opportunity to flow to the furthest areas of the mold. For very fine detail, speeds can be varied to throw the plastisol into the desired area forcefully, and molds can be so mounted that the displacement of this area from the axis of rotation becomes a significant factor.

Effect of Plasticizers on Plastisol Fusion

P. R. Graham and J. R. Darby
Organic Chemicals Division, Monsanto Chemical Co.

Microscopic measurement of the clear point of unfilled plastisols is a good method of showing the power of various plasticizers to promote fusion

Plasticizer structure has a profound effect on plastisol fusion. Attempts to relate the effects of specific structures on the fusion rates of plastisols have been made in the past. Severs (6) related solubility parameters for a number of plasticizers to clear points of dilute plastisols prepared from them. McKenna (5) studied the effect of temperature on plastisol fusion through the observation of ultimate integrity of film cast along a temperature gradient plate.

This article describes a quick and simple method of determining the clear point of unfilled plastisols. Data are presented which provide an estimation of the relative fusion powers of a number of plasticizer-types. The relative fusion points observed by this test are related to the rate of physical property (tensile strength and elongation) acquisition of plastisols prepared from specific plasticizers.

Preparation of Plastisols

The following basic plastisol formulation was used in this study:

Poly (vinyl chloride) paste resin	100
Plasticizer	65
Epoxidized soy bean oil	3
Liquid Ba/Cd/Zn stabilizer	2
Triphenyl phosphite	½

The resin was weighed into the container of the Model N-50 Hobart Mixer. Agitation was started and enough of the liquid ingredients was added until a heavy, dough-like consistency was formed. Mixing was continued for five minutes before the remainder of the liquid was added. The batch was then allowed to mix for an additional 40 minutes. After mixing, each plastisol was deaerated.

Fusion Point Determination

A small drop of plastisol (ca. 1 mm dia.) was placed on a circular cover glass. A similar glass was used as a cover. This assembly was placed on the stage of a Fisher-Johns Melting Point Apparatus. The rheostat on the instrument was set so as to allow a temperature rise of 2°C./min. The temperature was read on a thermometer inserted into the heated block. The temperature at which the plastisol becomes clear was recorded as the relative fusion point.

In some systems, a close similarity between the refractive index of the plasticizer and that of the resin produced plastisols which were clear at room temperature. In these cases, the particular plasticizers were mixed in various proportions with a plasticizer producing opaque plastisols. A plot was made and the straight line extrapolated to 100% of the "test" plasticizer and the fusion point recorded.

Physical Property Determination

The plastisols were poured into the concave sides of a one-quart paint can lid to the depth of about 0.01 in. The lids were then placed in an air circulation oven equipped with a rotating table to insure uniform heat experience for each plastisol. The oven was pre-set to the desired temperature with the air intake open. Samples of each plastisol were removed at measured time intervals and allowed to cool. The cast plastisols were then stripped from the can lids and allowed to condition at 23°C. for 24 hours. Miniature dumbbell specimens were cut from the center of the casting using a specially constructed die having a width of 0.010" and a neck length of 0.5". Tensile strength, ultimate elongation and modulus were determined on a Model TTS Instron Tester. The crosshead speed was set at 10 in./min. The materials used in this study are listed in *Table 1*.

When a plastisol is exposed to elevated temperatures several changes occur which are dependent upon the temperature level and the time. Plastisol viscosity decreases early during exposure and is usually proportional to the viscosity index of the pasticizer. However, if the temperature is high enough, this early reduction in viscosity is brief. The dispersion soon passes through a gel stage, rapidly becomes a solid and soon (depending upon plasticizer type) acquires considerable integrity resulting in a cohesive film of ultimate mechanical properties. This stage is considered to be the optimum fusion point. Finally if allowed to remain for longer periods at elevated tempera-

Table 1. Directory of Plasticizers and Their Fusion Points

Chemical Name	Abbreviation or Trade Name	Supplier	F.P., °C.
Dibenzyl Phthalate	DBzP	Monsanto Laboratory Synthesis	80
Phenyl Cresyl Phthalate	φCP	Monsanto Laboratory Synthesis	81
Dimethyl Phthalate	DMP	Monsanto Chemical Company	88
Phenyl Benzyl Phthalate	φBP	Monsanto Laboratory Synthesis	88
Butyl Benzyl Phthalate	Santicizer 160	Monsanto Chemical Company	89
Triethyl Phosphate	TEP	Monsanto Laboratory Synthesis	90
Dibutyl Phenyl Phosphate	DBu φP	Monsanto Laboratory Synthesis	90
Tricresyl Phosphate	TCP	Monsanto Chemical Company	92
Diethyl Phosphate	DEP	Monsanto Chemical Company	92
Butyl Cyclohexyl Phthalate	Elastex 50-B	Barrett Division	92
Triphenyl Phosphate	TφP	Monsanto Chemical Company	96
Dibutyl Phthalate	DBP	Monsanto Chemical Company	97
Phenyl Dicresyl Phosphate	Santicizer 140	Monsanto Chemical Company	100
Isoactyl Diphenyl Phosphate	Santicizer 144	Monsanto Chemical Company	101
Di-2-ethylhexyl Phenyl Phosphate	DOφP	Monsanto Chemical Company	102
Tributyl Phosphate	TBuP	Monsanto Chemical Company	103
Dimethyl Adipate	DMA	Monsanto Laboratory Synthesis	104
Octyl Cresyl Phthalate	OCP	Monsanto Laboratory Synthesis	104
2-ethylhexyl Diphenyl Phosphate	Santicizer 141	Monsanto Chemical Company	105
Modified Phthalate Ester	Santicizer 213	Monsanto Chemical Company	105
Diethyl Adipate	DEA	Monsanto Laboratory Synthesis	106
Diphenyl Phthalate	DφP	Monsanto Chemical Company	108
Dipropylene Glycol Dibenzoate	Benzoflex 988	Tennessee Products Company	108
Di-n-Propyl Adipate	DPA	Monsanto Laboratory Synthesis	111
Di-n-hexyl Phthalate	DHP	Monsanto Laboratory Synthesis	113
Dibenzyl Adipate	DBzA	Monsanto Laboratory Synthesis	114
Isodecyl Diphenyl Phosphate	IDDφP	Monsanto Laboratory Synthesis	114
Isodecyl Dicresyl Phosphate	IDDCP	Monsanto Laboratory Synthesis	117
(Butyl octyl) Phthalate	Santicizer 165	Monsanto Chemical Company	119
Tri-n-hexyl Phosphate	THP	Monsanto Laboratory Synthesis	121
Butyl Decyl Phthalate	Santicizer 603	Monsanto Chemical Company	122
Diisoctyl Phthalate	DIOP	Monsanto Chemical Company	126
Di-2-ethylhexyl Phthalate	DOP	Monsanto Chemical Company	127
Di-n-octyl Phthalate	DNOP	Monsanto Laboratory Synthesis	127
Di-n-octyl Phenyl Phosphate	DnOφP	Monsanto Laboratory Synthesis	128
Di-2-ethylhexyl Phenyl Phosphate	DOφP	Monsanto Laboratory Synthesis	128
Di-2-ethylhexyl Isophthalate	Flexol 380	Union Carbide Chemicals Corp.	129
Dibutoxyethyl Adipate	Santicizer 151	Monsanto Chemical Company	135
Dicapryl Phthalate	DCP	Rohm and Haas Company	137
Diisodecyl Phthalate	DIDP	Monsanto Chemical Company	138
Di-2-ethylhexyl Hexahydrophthalate	Flexol CC-55	Union Carbide Chemicals Corp.	138
Di-n-Nonyl Phthalate	DnNP	Monsanto Laboratory Synthesis	139
Di-2-ethylhexyl Terephthalate	DOTP	Monsanto Laboratory Synthesis	140
Hydrogenated Terphenyl	HB-40	Monsanto Chemical Company	142
Di-n-decyl Phthalate	DnDP	Monsanto Laboratory Synthesis	143
Dioctyl Adipate	DOA	Monsanto Chemical Company	144
Modified Phthalate Ester	Santicizer 214	Monsanto Chemical Company	146
Di-2-ethylhexyl Azelate	DOZ	Emery Industries	149
Polyester Plasticizer	Santicizer 409	Monsanto Chemical Company	153
Alkyl Aromatic Hydrocarbon	HB-20	Monsanto Chemical Company	154
Ditridecyl Phthalate	DTP	Monsanto Chemical Company	155
Di-2-ethylhexyl Sebacate	DOS	Rohm and Haas Company	155
Diisodecyl Adipate	DIDA	Monsanto Chemical Company	156
Di-n-decyl Adipate	DnDA	Monsanto Laboratory Synthesis	158

tures, the film begins to degrade and lose the mechanical properties and to discolor. The rates at which these changes occur are different for each plasticizer.

As previously mentioned, the fusion point test is a micro determination of the temperature at which no discreet resin particles could be observed in a plastisol. It is assumed that this clear point represents the temperature (or quite close to the temperature) at which the resin-plasticizer system became homogeneous and that this point of homogeneity would be related to the point of ultimate film integrity. Measurements of fusion points of various plasticizers do, in fact, align the plasticizers in their relative positions in a fusion scale which would be predictable on the basis of plasticizer structure (1, 2) and processing data from plant operations (3). *Table 2* shows the comparison of fusion points to Banbury mixing times for a number of common plasticizers.

To check the validity of the micro test, the fusion point data were related to actual physical property measurements taken on plastisols exposed to elevated temperatures for selected time increments. *Figure 1* shows the elongation development of a group of plastisols subjected to 150°C for various times. It is obvious that the rates of elongation acquisition are quite different depending upon the plasticizer used. It is seen that Santicizer* 160 (butyl benzyl phtha-

* **Santicizer**—Registered Trademark of Monsanto Chemical Company.

Table 2. Correlation of Banbury Times and Relative Fusion Points

Banbury Data		Fusion Point Data	
Plasticizer	Time, sec.	Plasticizer	F. P., °C.
Santicizer 140	39	Santicizer 160	89
Santicizer 160	47	TCP	92
Santicizer 141	49	Santicizer 140	100
TCP	56	Santicizer 141	105
DOP	71	DOP	127
DOA	106	DOA	144
Paraplex G-50	283	Paraplex G-50	153

Table 3. Comparison of Physical Property and Fusion Point Determinations

	Fusion Rate $\frac{\Delta \text{ Elong}}{\Delta T(0\text{-}10 \text{ min})}$	Fusion Point, °C.
S*-160	29	89
S*-141	22	105
DOP	19	127
DOP/HB-40(3:1)	18	131
DIDP	10	137
TOF	9	138
DIDA	2	156

* **Santicizer**—Registered Trademark of Monsanto Chemical Co.

late) acquires elongation at a much faster rate than the other plasticizers considered. Next comes Santicizer 141 (2-ethylhexyldiphenyl phosphate), followed by DOP (di-2-ethylhexyl phthalate). It is seen that DIDA (diisodecyl adipate) is extremely slow in acquiring physical properties at this temperature. A fusion rate was calculated for each plasticizer on the basis of the change in elongation for the first ten minutes:

$$\text{Fusion Rate} = \frac{\Delta \text{ Elong.}}{\Delta T(0\text{-}10 \text{ min.})}$$

Table 3 shows the fusion rates for a series of typical plasticizers as compared to the measured fusion points obtained from the micro test. It is seen that good correlation between the two methods exists. Butyl benzyl phthalate acquires integrity at the rate of 29 elongation units/min. at 150°C. DOP is intermediate with 19 elongation units/min. and DIDA the most difficult to fuse.

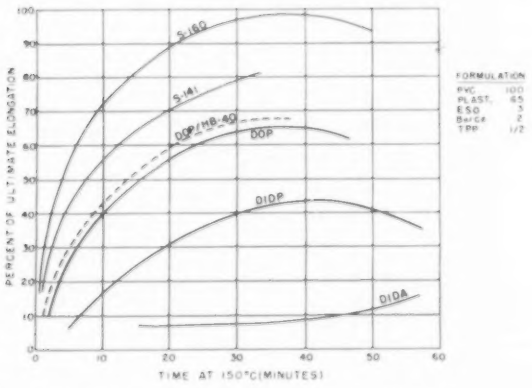

Figure 1. Elongation development vs. time

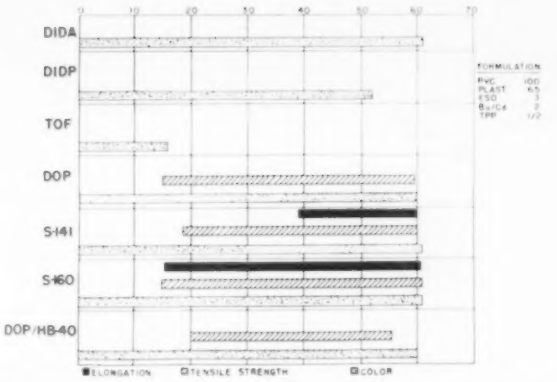

Figure 2. Duration of > 75% of ultimate physical properties (150°C)

Practical Aspects of Physical Property Determinations

The rates of physical property acquisition of the plastisols were determined at 150, 170 and 200°C. For practical purposes, it was assumed that if a plastisol could acquire and maintain at least 75% of its ultimate physical properties (elongation, tensile strength and color) it would be satisfactory for most applications. *Figure 2* depicts the duration of the useful physical properties (i.e. 75% of ultimate) for plastisols at 150°C. The ultimate physical properties are defined as those values of tensile strength, elongation and color which proved to be the highest at any of the temperatures involved for the particular plasticizer system. It is evident from *Figure 2* that butyl benzyl phthalate and phenyl dicresyl phosphate are the only plasticizers to develop 75% of their ultimate elongations and tensile strengths at 150°C. It is interesting to note that DOP does not acquire the 75% elongation but does begin to acquire that portion of its ultimate tensile strength. The plasticizers DIDA, DIDP (diisodecyl phthalate) and TOF (tri-2-ethylhexyl phosphate), never acquire the desired elongations or tensile strengths. It is also noted that in the case of TOF that the heat stability of this compound is so poor that its color becomes less than 75% of ultimate after only 12 minutes at 150°C. It is apparent that for applications where the plastic mass does not exceed 150°C., the use of a plasticizer with fusion power greater than that of DOP would be imperative.

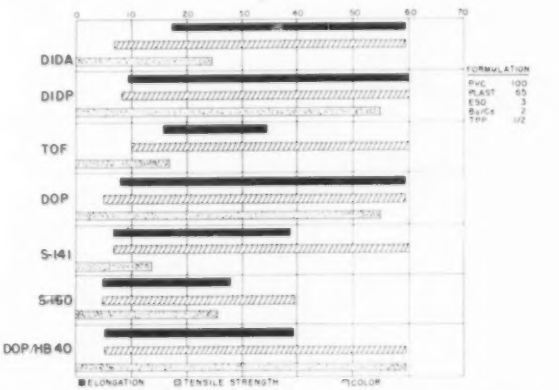

Figure 3. Duration of > 75% of ultimate physical properties (170°C)

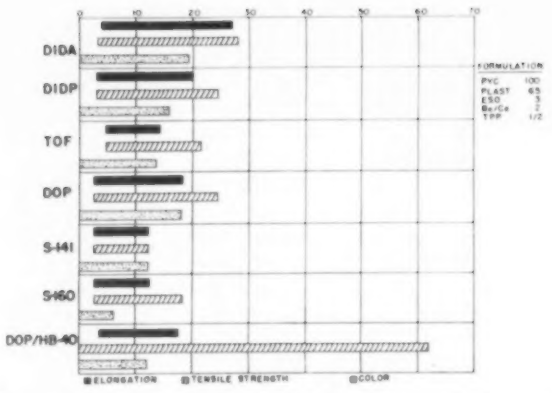

Figure 4. Duration of > 75% of ultimate physical properties (200°C)

Figure 3 is a similar study of the same plastisols at 170°C. There it is seen that all of the plasticizers (even DIDA) begin to acquire 75% of their ultimate physical properties. The plasticizers DOP, butyl benzyl phthalate, 2-ethylhexyl diphenyl phosphate and the DOP/HB-40* combination develop elongation and tensile strengths at about 5 minutes at 170°C. Degradation of some systems occur at this temperature. This is particularly true in the cases of the phosphate esters (2-ethylhexyl diphenyl phosphate and TOF) where both color and elongation are lost in comparatively short times. If the criterion of 75% physical property acquisition is valid, it would appear that the working times for some of these plasticizers would be restricted considerably at temperatures above 170°C.

The results at 200°C. are shown in *Figure 4*. It is apparent that all of the plasticizer systems become similar. It also indicates that the degradation factor is extremely critical. All of the plastisols develop physical properties early, however, they also degrade early as evidenced by their failure to maintain 75% of their ultimate properties over long exposure periods.

Effect of Plasticizer Structure on the Fusion Point of Plastisols

Phthalate Esters. In *Figure 5*, the fusion points of the phthalate esters are plotted against their molecular weights. A smooth line can be drawn connecting the points obtained from the n-alkyl phthalate esters. It is apparent that the relative fusion point increases as the alkyl chain becomes longer. The curve is extrapolated to the molecular weight of the unattached phthalate radical and a value of 84°C is obtained. This would theoretically indicate that a temperature of at least 84°C (on the basis of this test) would be required for the fusion of any alkyl phthalate plastisol and that the addition of each methylene group requires a definite temperature increment for fusion.

The phthalate esters containing phenyl, cresyl or benzyl groups have relative fusion points displaced somewhat lower than the alkyl phthalate curve. In the case of dibenzyl phthalate and cresyl phenyl phthalate the relative fusion points were observed to be even lower than the extrapolated value for the phthalate radical. This substantiates previous results [Banbury times (3), plastisol shelf life (4)] showing the beneficial effect of aromatic constituents on fusion. It is evident that benzyl and cresyl groups contribute more to fusion than phenyl groups. It is also indicated that chain branching in the alkyl alcohol portions results in lower fusion points than the same normal alkyl segment. Dicapryl phthalate (DCP) is an interesting case. Although being an octyl phthalate, its fusion point is considerably higher than DOP. Part of this difference can be explained by the longer base chain length since DCP is 1-methyl *heptyl* phthalate and DOP is 2-ethyl *hexyl* phthalate. It is also possible the rest of the difference is due to the secondary alcohol structure in DCP.

Aliphatic Esters. A similar plot for the adipate esters can be found in *Figure 6*. As in the phthalate study the fusion point increases steadily with molecular weight. The extrapolated value for the unattached adipate radical is 104°C., theoretically indicating that this temperature must be achieved (according to this test) before any adipate will fuse with Opalon 410. This temperature, as compared with the 84°C obtained for the unattached phthalate radical, correlates with the difficult fusion conditions required for the adipate esters. The value for dibutoxyethyl adipate falls on the curve at about the same location as would be expected from a diheptyl adipate molecule indicating that the pair of ether linkages in DBCA function as carbon atoms. The values for the azelate and sebacate esters are appropriately displaced higher than the corresponding adipate esters. The beneficial effect of aromatic derivatives is also shown.

Phosphate Esters. *Figure 7* shows the effect of molecular weight on the fusion points of the phosphate esters. The trifunctional character of the phosphate radical complicates the picture to some extent. A straight line can be drawn between the values obtained for the alkyl aryl phosphate esters. The substitution of aryl groups for any of the alkyl groups lowers the fusion points and form curves of various slopes depending upon the types of groups present. The extrapolated value for the phosphate radical was calculated at 78°C. This is also in conformity with other data showing phosphate esters to be generally easier to fuse than the phthalate (on a M. W. basis). As in the phthalate and adipate studies, the introduction of aryl groups into the molecule lowers the fusion point.

Specific Acid and Alcohol Groups. *Table 4* ranks each of the ester types according to their extrapolated relative fusion points. The phosphate esters are the easiest to fuse, followed by the phthalate and finally the aliphatic esters. In the aliphatic ester series the longer chain dicarboxylic acid esters are more difficult to fuse.

By subtracting the extrapolated value for each acid group from the relative fusion point another value can be obtained which would represent the estimation of the contribution of the alcohol groups to fusion. For example, DOP has a relative fusion point of 127°C. The extrapolated value for the phthalate radical is 84°C. Then:

Table 4. Extrapolated Relative Fusion Points of Acid Groups

	F. P., °C.
Phosphate	78
Phthalate	84
Isopthalate	95
Terephthalate	98
Adipate	102
Azelate	104
Sebacate	104

* HB-40—Registered Trademark of Monsanto Chemical Company.

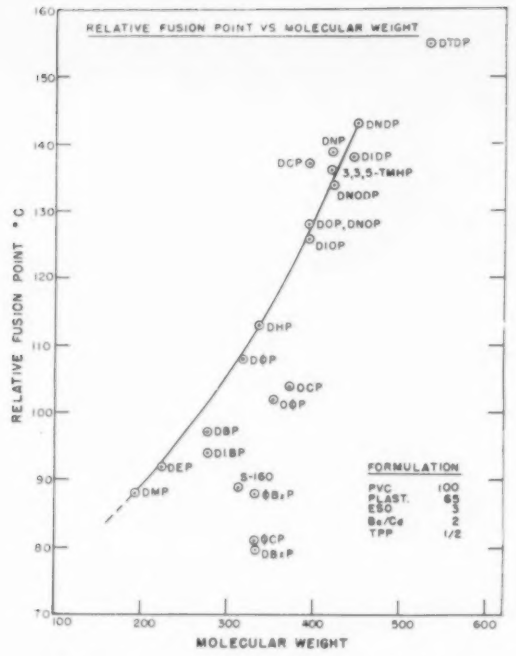

Figure 5. Relative fusion points of phthalate plasticizers

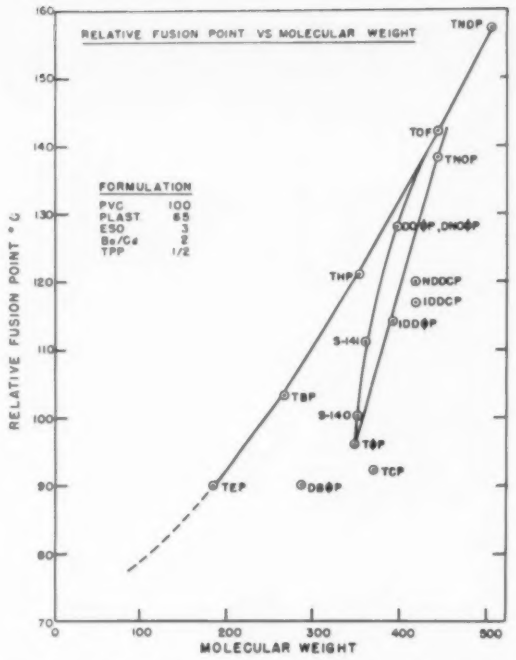

Figure 7. Relative fusion points of phosphate plasticizers

$127 - 84 = 43°C.$ required for both 2-ethyl hexyl groups or 21.5°C. for each octyl group.

It is possible to estimate the relative fusion point of a plasticizer system by adding the various temperature requirements for each acid and alcohol group calculated on a weight percent basis.

A list of the relative fusion points of commercial plasticizers are shown in *Table 1*.

Conclusions

A rapid method for estimating the relative fusion power of various plasticizers has been developed. This procedure based on the clear point of unfilled plastisols, has been correlated with ultimate physical property build-up observations. From the physical property study it was shown that only plasticizers of high aromaticity produced plastisols capable of being fused (at least 75% of ultimate physical properties) at 150°C. At 170°C all of the plasticizers studied began to develop physical properties and fuse. The problem of degradation is apparent at 200°C, indicating that a critical problem exists for many plasticizers by narrowing the workable temperature ranges. Fusion point data show that aromatic groups add to fusion power in a given plasticizer series. It was found that ease of fusion is generally in the following order for various ester-types: phosphates, phthalates, isophthalates, terephthalates, adipates, azelates, and sebacates.

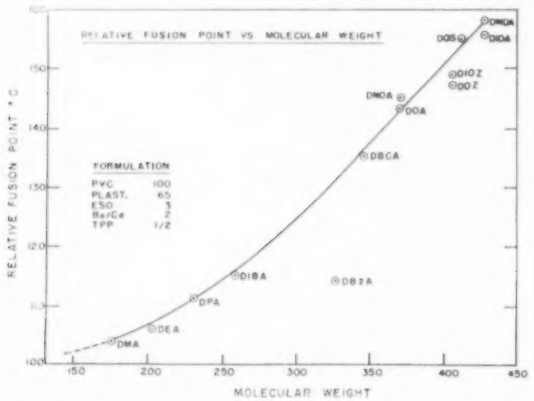

Figure 6. Relative fusion points of aliphatic plasticizers

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Acknowledgments

The authors acknowledge the help given by Dr. C. Anagnostopoulos in the interpretation of the micro clear point data. Thanks are also due to L. R. Lauck who aided in the acquisition of the data.

TO ALL READERS OF THE SPE JOURNAL:

Do you know:

Where to get the best line of formable plastic sheeting?

Do you know:

Nixon-Baldwin produces sheeting by the block, calender, and extrusion method? (It's the only company in the U. S. that does so.)

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Property	*ASTM No.*	*Value**
Impact strength, Izod (notched)	D-256 (½" x ½")	2 to 3 ft-lb/in.
	(½" x ⅛")	12 to 16 ft-lb/in.
Elongation, at yield	D-638	5-6%
Elongation, ultimate	D-638	60-100%
Deformation under load	D-621	0.14%
Flexural strength	D-790	11,000-13,000 psi
Dissipation factor	D-150	
60 cycles		0.0007
10^6 cycles		0.0100
Heat distortion	D-648	
264 psi		280°F
66 psi		290°F
Flammability (in./min.)	D-635	Self-extinguishing
Clarity		Transparent
Water absorption 24 hr. immersion	D-570	0.15%

*These values have been obtained under standard ASTM and laboratory test conditions. As averages, they do not necessarily represent minimum material specifications.

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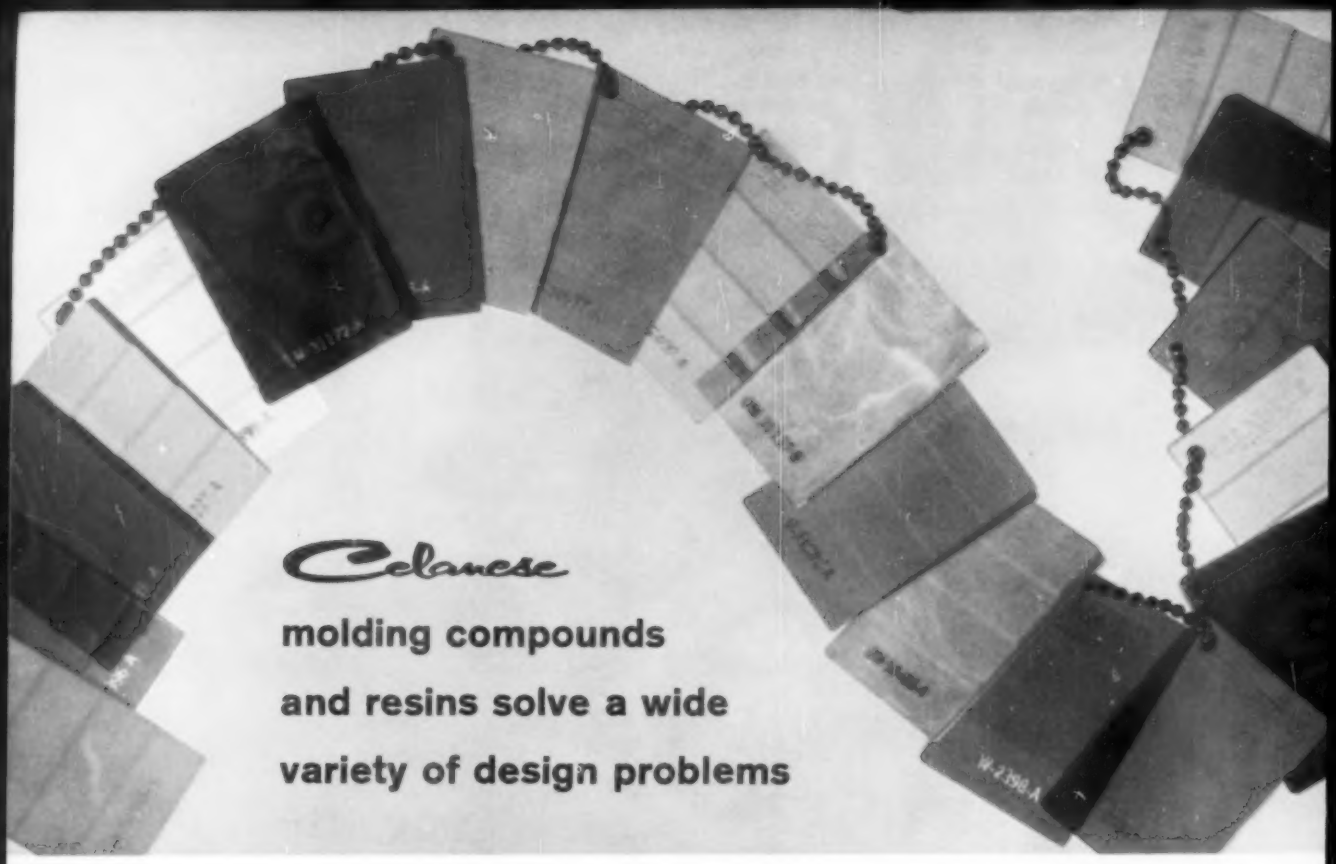
Acetate, Propionate and Triacetate
CELLULOSE FLAKE

★ ★ ★

TECHNICAL SERVICE



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Celanese offers cellulose acetate, cellulose triacetate and cellulose propionate flake in a variety of grades to basic industries such as plastics, sheet, film, fibers, protective coatings and adhesives. Specific applications include lacquer for paper, wire, and flashbulb coatings; film and sheeting for photography, graphic arts, and transparent packaging; molding powder for extrusion and injection molding of tool handles, tubing, and toys; and binders for color concentrates.

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Available in any color, Ferro's non-dusting pigments improve color dispersion, eliminate troublesome dusting (often the cause of color contamination), facilitate the use of pneumatic devices for the transfer of the resin-colorant mixture from tumbling drums to hoppers.

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THE AUTOMOTIVE INDUSTRY

WARMS UP TO BLOW MOLDING

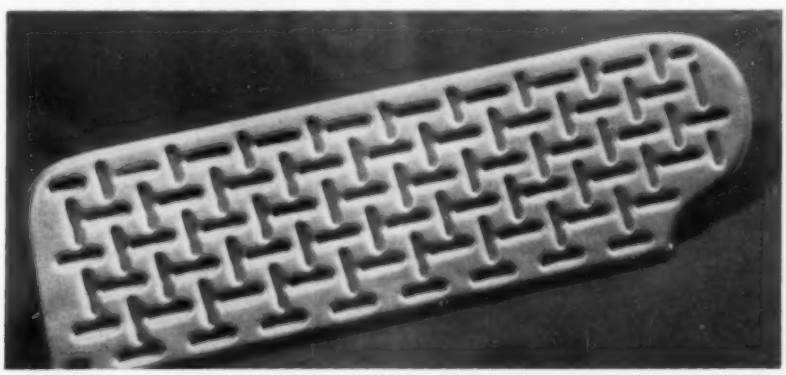
Keeping pace with design advances, the Chrysler Corporation investigated blow molding and found these heater ducts to be both functional and economical. Each is blow molded—in one piece—of BAKELITE Brand high density polyethylene. They're tough but light in weight. And though they are large and complex, the production rate is high.

These ducts prove that the blow molding of polyethylene reaches far beyond the realm of containers—that it is a practical, efficient and economical method for producing large or small, simple or complex parts.

The first consideration for the effective blow molding of such parts is the selection of the proper polyethylene. Union Carbide offers the greatest variety of polyethylenes available at one source—high, low or medium density, and copolymers. This means you are sure to find a formulation suited to your application.

What's more, you can call on Union Carbide for technical aid in blow molding it to best advantage. Union Carbide's experience in blow molding polyethylenes dates back almost as far as the technique itself, and has progressed as rapidly.

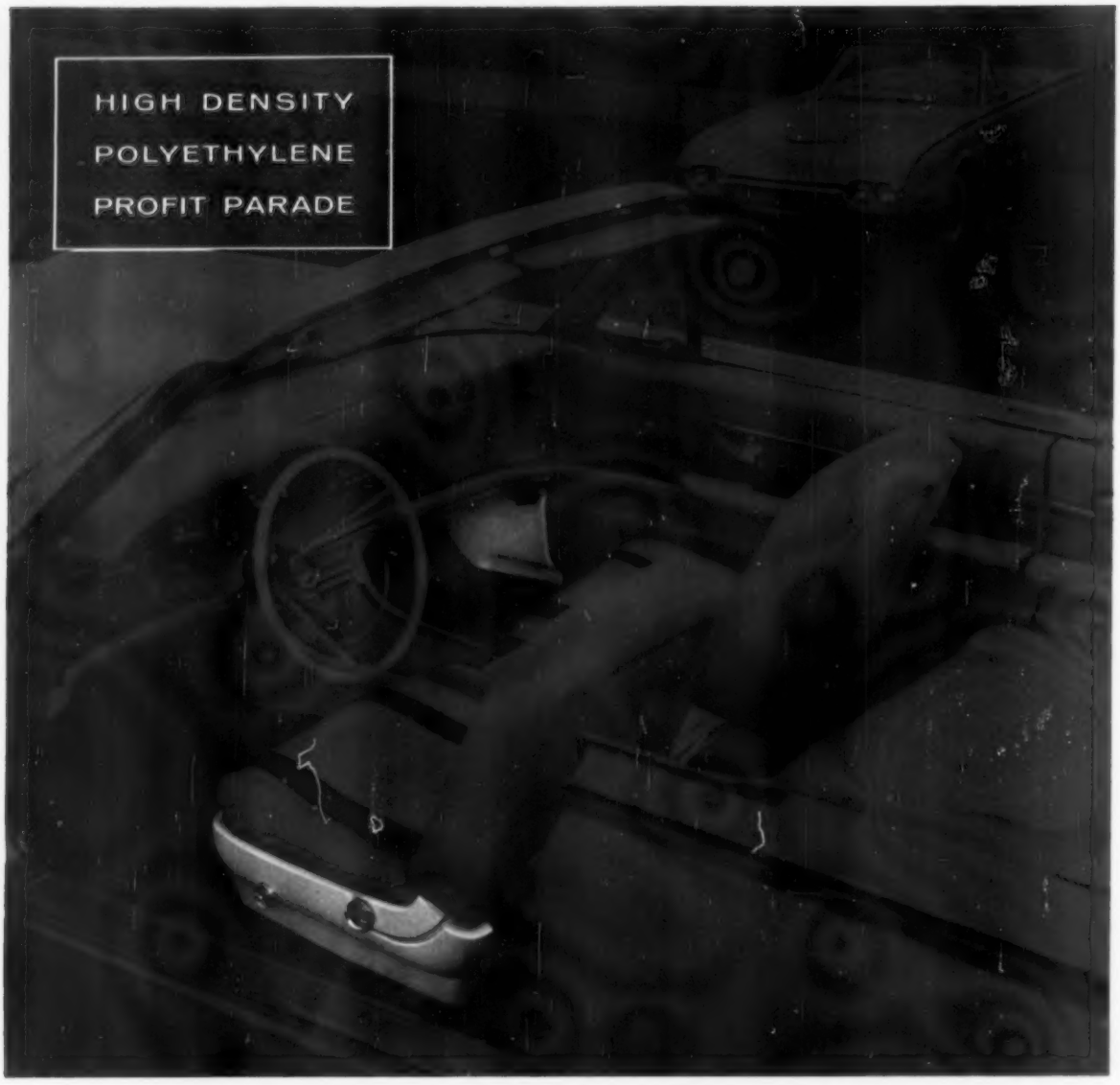
Remember, for design advancements in plastics, you'll find the materials and the experience at Union Carbide Plastics Company. For information write Dept. IA-132, Union Carbide Plastics Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, New York. *In Canada:* Union Carbide Canada Limited, Toronto 12.



The heater ducts (left) were blow molded for the Chrysler Corporation by Woodall Industries, Detroit, Michigan. **Prototype blow-molded sun visor (above)** also by Woodall illustrates the design flexibility of blow molding for automotive applications.

UNION CARBIDE

BAKELITE and UNION CARBIDE are registered trade marks of Union Carbide Corporation.



Grace Plastic Adds to Lasting Value of Classic Car

The beautiful, classic Thunderbird is a king in Ford Motor Company's famous line. And as befits a king, all its parts and appointments are made with special care, for lasting beauty, value and service . . . while maintaining realistic economies.

Example: Grex High Density Polyethylene is a material used in three "show" parts of this '61 model—in the side cowl cover, the side seat shield, and the pivot cap on the seats. Besides having smooth beauty, these parts also must be scuffproof. And they must be perfectly color-matched with other parts of the interior.

Grex is an excellent material for components such as these, where beauty, duty and economy of fabrication must go hand in hand. Grex can be formed by any conventional fabricating technique, in any color. It takes day-after-day punishment without chipping, cracking or breaking. It can undergo extremes of temperature without losing its strength or shape. And most important of all, it adds beauty and value to this car.

If you need the special advantages of high density polyethylene, don't overlook the experts. Grace has the production facilities, technical service and experience to help with demanding components problems. And we're easy to do business with.

Grex is the trademark for W. R. Grace & Co.'s Polyolefins

W.R. GRACE & CO.
POLYMER CHEMICALS DIVISION
CLIFTON, NEW JERSEY

'61 Thunderbird sets
a standard for value.

Color is critical. As every auto buyer knows, cars are made in almost every color of the spectrum. Ford, in its Thunderbird line alone, uses 6 colors. Grex already has been supplied in all of these approved colors.

Matching colors to the most critical standards requires ingenuity, patience and experience. For colors must not only pass stringent visual tests under the Macbeth light, but must stand the test of time as well.

Wearing qualities essential. There would be little virtue to parts made of Grex if they merely appealed to the eye. All the parts are in "wear" locations, and are subject to scuffing or continual flexing. The problem of scuffing is overcome with a handsome, textured, leather-like effect. Scuffs literally "bounce off." This textured pattern was engraved in the irregular surface molds by photo arc.

The side cowl cover presented a special problem. It is thin-gauge, yet has large surface area. High density polyethylene was selected as the material for this part because it resists abrasion, withstands flexing, and has native toughness, even in very thin, large-area sections.

Why not use some other material? High density polyethylene has special advantages in applications like these. It requires no additional surface finish, and gives close color match. It has a warmth and solidity lacking in other materials. It doesn't chip, crack, or peel. Perhaps most important, it maintains economies while actually improving the quality look of components.

What about you? The problems present in this application can be applied profitably in other products. Luggage, for instance. And housewares, appliance components, quality toys. If you'd like a profitable answer to a high density polyethylene question, just write us:

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TECHNICAL MEETINGS CALENDAR

17th ANTEC

Annual Technical Conference—January 24-27, 1961, Shoreham and Sheraton Park Hotels, Washington, D.C. Sponsored by the Baltimore-Washington Section. General Chairman: Dr. Gordon Kline, National Bureau of Standards, Washington, D. C.

1961 RETECS

March 14—Plastics Finishing Seminar sponsored by Southern California Section with cooperation of Finishing PAG, Roger Young Auditorium, Los Angeles, Calif. Chairman: Milton T. Schimmel, c/o Decorative Engineering and Supply, Inc., 17000 South Western Ave., Gardena, Calif.

April 4-5—Plastics Injection Molding Workshop sponsored by Pioneer Valley Section with cooperation of Injection Molding PAG, Holy Cross College, Worcester, Mass. Chairman: Roger Johnston, c/o Foster Grant Co., Inc., 289 North Main St., Leominster, Mass.

April 20—Plastics—A New Dimension in Buildings sponsored by Western New England Section with cooperation of Plastics in Buildings PAG, Springfield Museum of Art, Springfield, Mass. Chairman: Robert W. Sherman, c/o Union Carbide Plastics Co., 410 Asylum St., Hartford 3, Conn.

May 9— Plastics in the Automotive Industry sponsored by Detroit Section with cooperation of Plastics in the Automotive Industry PAG, Detroit Mich. Co-Chairmen: John A. McPherson, c/o Underground Products Inc., 12801 Inkster St., Livonia, Mich., and John J. Doyle c/o Rohm & Haas Co., 20211 Greenfield St., Detroit 35, Mich.

June 6—Plastics in Packaging sponsored by Quebec Section, Montreal, Quebec, Canada. Chairman: Ralph Noble, c/o Canadian Industries, Ltd., P.O. Box 10, Montreal, Quebec, Canada.

September 12—Plastics for Tooling sponsored by Central Indiana Section, Hotel Severin, Indianapolis, Ind. Chairman: Eugene C. Quear, c/o Delco-Remy Division, General Motors Corp., 2401 Columbus Ave., Anderson, Ind.

October 5—Plastics Foams sponsored by Buffalo Section. Section President: William Dunmyer, c/o The Carborundum Co., Building 71-1, Buffalo Ave., Niagara Falls, N. Y.

October 25—Plastics in Major Household Appliances sponsored by Kentuckiana Section, Louisville, Ky, Chairman: Ray E. Eshenaur, c/o General Electric Company, AP-5-249, Appliance Park, Louisville, Ky.

November 2-3—Plastics in Packaging and Engineering Exhibition on November 1, 2, 3. RETEC sponsored by North Texas Section and Exhibition by Section with cooperation of Southwestern Division Chapter, Society of Packaging and Handling Engineers, Sheraton-Dallas Hotel, Dallas, Tex. Chairman: Peter W. Kent, 3637 Mid Pines Drive, Dallas 29, Texas.

November 15— Vinyl Plastics in the Household sponsored by New York Section with cooperation of Vinyl Plastics PAG, Statler Hilton Hotel, New York, N. Y. Chairman: Saul Gobstein, c/o Ferro Chemical Co., Box 607, Emerson, N. J.

December 1—Plastics Screw Injection Molding sponsored by Cleveland Section, Cleveland Engineering Society Building, Cleveland, Ohio. Chairman: Edward J. Haskins, c/o Injection Molders Supply Co., 17601 South Miles Road, Cleveland 28, Ohio.

Offers of papers for presentation at these Regional Technical Conferences are invited. Please address offers to RETEC Chairman or Section President.

— INTERNATIONAL PLASTICS SHOW —

June 21-July 1—International Plastics Exhibition and Convention, Olympia, London England. Organized by **British Plastics**. Address inquiries to: Interplas '61, Dorset House, Stanford St., London S. E. 1, England.

POLYMER SYMPOSIUM

July 27-August 1, 1961, International Symposium on Macromolecular Chemistry, Montreal, Canada. Address inquiries to: The Organizing Committee International Symposium on Macromolecular Chemistry, P.O. Box 816, Sarnia, Ontario, Canada.

JOINT SEMINAR

March 15— Plastics for Tooling jointly sponsored by American Society of Tool and Manufacturing Engineers and SPE Casting and Plastics Tooling Professional Activity Group, Statler-Hilton Hotel, Detroit, Michigan. SPE Program and CPTPAG Chairman: Lawrence Wittman, c/o L. Wittman & Co., 1395 Marconi Blvd., Copiaque, N. Y.

SPI EVENTS—1961

February 7, 8, 9—Sixteenth Reinforced Plastics Division Conference, The Society of the Plastics Industry, Inc., Edgewater Beach Hotel, Chicago, Ill.

April 20, 21—Eighteenth Annual SPI Western Section Conference, The Society of the Plastics Industry, Inc., Hotel del Coronado, Coronado, Calif.

June 5-9—Ninth National Plastics Exposition, Sponsored by The Society of the Plastics Industry, Inc., Coliseum, New York City.

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Now available in pellet form, STAN-TONE PE Colors minimize dusting and combine exceptional heat and light stability with high resistance to migration, crocking, leaching and bleed. Excellent in high-density polyethylene applications. STAN-TONE PE Colors are ideal for use in polyethylene containers, film, filament, pipe and wire and cable.

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SOCIETY ACTION

Revised Organization to Streamline SPE Management

R. Kenneth Gossett

Chairman, Committee on Organization of the Future Management of the Society

A revised organization of the management of the Society recommended by our Committee was adopted by Council at its meeting in New York City on October 18, 1960. If the By-Laws necessary to implement it are adopted at the meeting of Council on January 23, 1961, the new organization will become effective immediately. Its purpose is to adapt the management of the Society to meet today's and tomorrow's requirements. Its need has been made urgent by the increasing load placed upon the present management by the rapid growth of our Society.

One of the major benefits will be to separate the scientific and engineering functions of the Society from the administrative functions through separate Engineering and Administrative Boards, thus assuring that each receives the attention due it. By screening proposals and policies in their areas, and submitting them to Council with their recommendations, these Boards will not only give Council the benefit of their specialized knowledge, but also will relieve Council of much of its former load.

Council

Council retains all of its present powers as the Society's top governing body but will delegate more of them to an expanded Executive Committee and some of them to the Engineering and Administration Boards, thus permitting each Council to meet only three times annually. For example, the 1961 Council will meet first at the 17th ANTEC in Washington, D. C. on January 25, 1961; again in the fall—within 30 days of October 1 for election of Officers; and finally at the 18th ANTEC in Pittsburgh, to conclude the year's business.

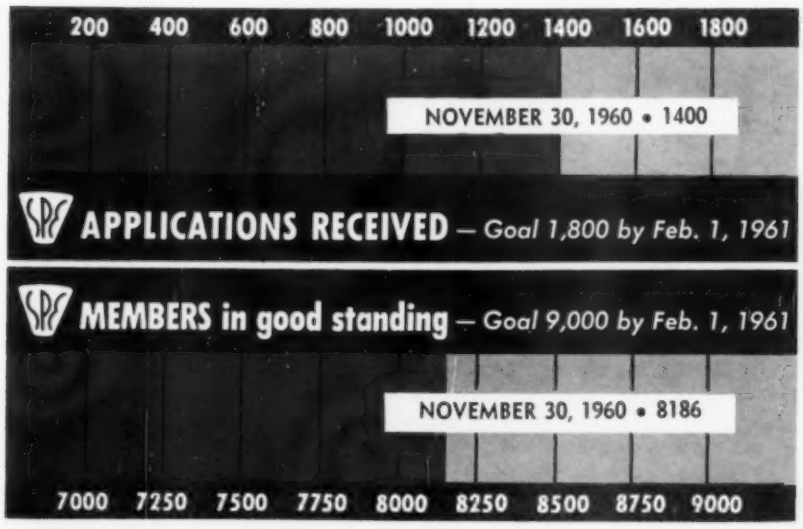
At the first meeting of each Council it will approve a budget for the next fiscal year.

To assist Councilmen to vote intelligently for Officers at the fall meeting, each Councilman will be sent in advance biographies and photographs of all Councilmen eligible for Office and the list of Councilmen nominated by the Nominating Committee.

It shall be mandatory instead of optional for all elected Officers to assume the status of Councilmen-at-Large during their term of office. This means that, if a Councilman representing a Section is elected an Officer, his Section Board must elect another Section representative to serve on Council during the Officer's term, as specified in By-Law B-22.

Executive Committee

Executive Committee is expanded by increasing the number of Presidential appointees from two to four. Two of the appointees will serve as Vice Chairmen and Committee Administrators of the Engineering Board and two in the same capacity for the Administrative Board.



New Member Goal in Sight

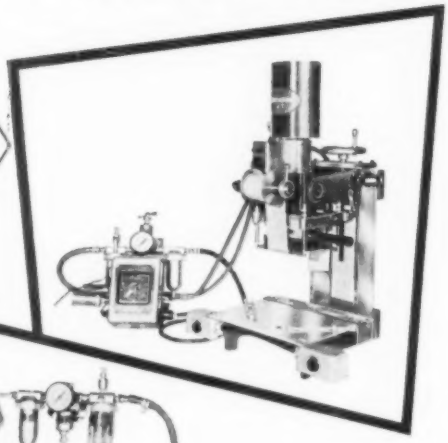
An average of 200 per month will attain the Membership Committee's goal. Let's all convince that associate "who ought to be a member but isn't" to submit his application right now.

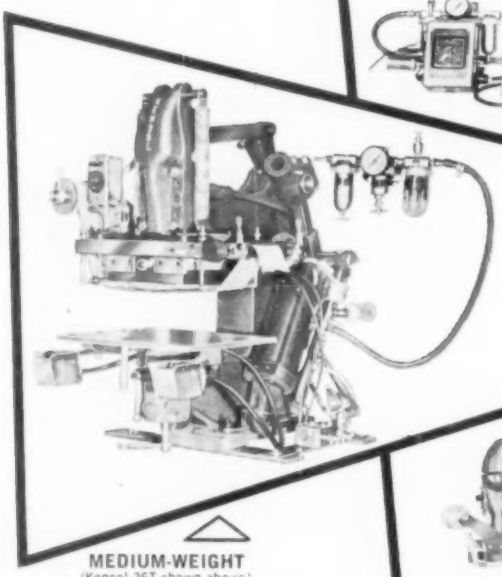
KENSOL HOT STAMPING PRESSES

...the Best Solution to your Marking and Decorating Problems

LIGHT-WEIGHT
(Kensol 15T shown at right)

A ruggedly built, small hand-operated or power machine with a 2 x 4 inch impression area, and a 2 inch head stroke. The economically priced Kensol 15T air-operated press is equipped with a thermostatic heat control, adjustable electric dwell-timer, Norgren air controlling unit, etc. for high speed, fine quality marking, utilizing unskilled help.



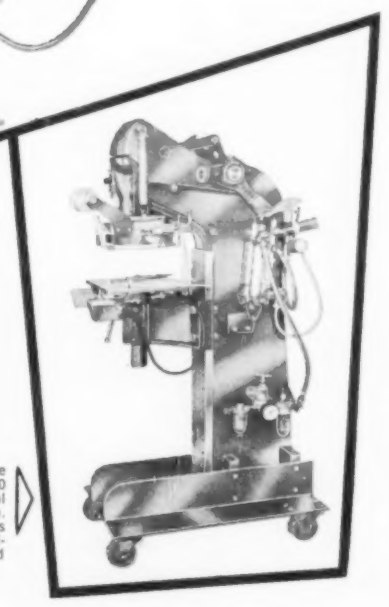


MEDIUM-WEIGHT
(Kensol 36T shown above)

The most popular hot stamping press in use today. Known for its accuracy and dependability. Hand or air-operated, rugged cast iron "C" frame construction, with a 6 x 8 inch or 5 x 12 inch impression area, and a 3 inch head stroke. Now available with either the new side to side, or the standard front to back roll leaf attachment.

HEAVY-DUTY
(Kensol 110 shown at right)

The heavy duty series consists of three models: Kensol 50 for flat work, Kensol 60 for items up to 6 inches high, and the Kensol 110 (shown) for items up to 24 inches high. Equipped with one or two main air cylinders (for added power), these presses are available with 6 x 9, 9 x 12, 10 x 15 inch and special larger impression areas.



WRITE FOR COMPLETE LITERATURE

Complete literature on these and other Kensol models will be sent on request. Brochure also shows automatic feeding devices.

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To assure Regional Representation, the four appointed Executive Committee members shall come from Regions other than the Officers' Regions up to the point that as many SPE Regions as possible are represented in the Executive Committee.

Officers

The present First Vice President will become Vice President, Engineering, and the Second Vice President—Vice President, Administration.

Engineering Board

The new Engineering Board shall establish and maintain policies to coordinate and direct all technical activities of the Society including technical aspects of Professional Activity Groups, Education, Inter-Society Relations, Publications, Technical Volumes, Technical Programs, and Meetings. The Board consists of a minimum of 12 Senior Members, the Vice President, Engineering, who shall be Chairman, and two Vice Chairmen appointed by the President from the Executive Committee who, also, will serve as Committee Administrators. The first Engineering Board will be appointed by the Vice President, Engineering subject to approval of Council, to represent the various facets of plastics engineering (extrusion, injection molding, vinyl, etc.). Thereafter, one-third of the membership of the Engineering Board shall retire each year and be replaced through election of members of the Engineering Board for terms of three years.

Administrative Board

The new Administrative Board shall establish and maintain policies to coordinate and direct all administrative activities of the Society, including Finance, Constitution and By-Laws, Election Inspectors, Nominating, Public Relations, Membership, Credentials, Sections and New Sections. The Board consists of the chairmen of the administrative committees, the Vice President, Administration, who shall be Chairman, and two Vice Chairmen appointed by the President from the Executive Committee who, also, will serve as Committee Administrators.

A complete chart of the new organization will be published in the February, 1961 issue of the SPE Journal.

—■—

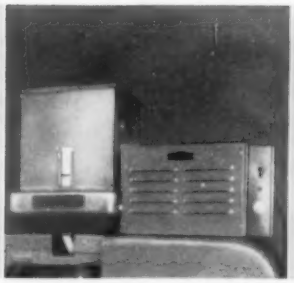
Edited by
Thomas A. Bissell,
SPE Executive Secretary

THORESON-McCOSH, INC.

SERVING THE PLASTICS INDUSTRY

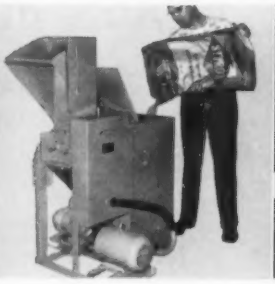
1 **Hopper-dryer and Jet hopper loader**

More production, lower costs, higher products quality because of properly controlled conditioning of material, no compressed air. Easy installation in minutes.



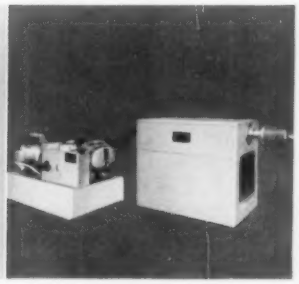
2 **Thoreson-McCosh Hopper-dryer**

Dries and preheats material at less cost than conventional drying ovens. Easy installation on standard injection and extrusion machines. No compressed air.



3 **Shearway granulator, blender and loader**

Granulates and loads in one operation. With our Hopper-dryer it is the most effective drying, loading, granulating, blending unit obtainable. No compressed air.



4 **Thoreson-McCosh new Hi-dri unit**

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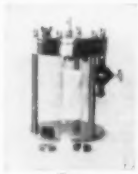

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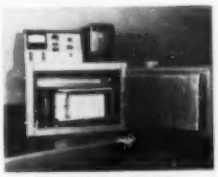

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PAGs at ANTEC

. . . summit meetings in plastics engineering

Frank W. Reynolds
PAG Administrator

To SPE's 16 Professional Activity Groups ANTEC is the double-barreled climax of a year of hard work. On the one hand, it is the focal point of the past year's activities in both technical programming and all other types of projects. On the other, the Conference serves as the pad from which PAG projects of the future are launched.

These new projects, to be of greatest value to the specific segment of the plastics industry served by the PAG, must also reflect the needs and desires of PAG members. While the PAG Officers and Executive Committees are responsible for implementing the projects, it is the responsibility of each individual member to express his views in selecting these projects.

ANTEC provides the greatest single opportunity available to the plastics industry to gather together in one room those engineers and scientists interested in one specific phase of plastics. To capitalize on this opportunity, ample time, starting at 3:30 P.M. on each afternoon of ANTEC, has been set aside for PAGs to meet. Wherever possible, these meetings follow or precede technical sessions on the same or similar subjects. And most important, no technical sessions are scheduled during PAG meetings.

The complete schedule, including room locations in the Shoreham Hotel, follows:

PAG	Meeting Location
3:30 P.M., Tuesday, January 24	
Plastics in Electrical Insulation	Park Room
Extrusion	Terrace Banquet Room
Reinforced Plastics	West Ballroom
Thermosetting Molding	Main Ballroom
Standards for Reporting Properties	North Room
Coloring of Plastics	South Room
3:30 P.M., Wednesday, January 25	
Plastics in Buildings	West Ballroom
Injection Molding	Main Ballroom
Casting and Plastics Tooling	North Room
Polymer Structure and Properties	Terrace Banquet Room
Plastics in the Automotive Industry	South Room
3:30 P.M., Thursday, January 26	
Metal Mold Design and Construction	West Ballroom
Forming	South Room
Finishing	Park Room
Vinyl Plastics	Main Ballroom
Blow Molding	Terrace Banquet Room

A number of PAGs plan to include technical speakers or panels in the agenda of their meeting. Thus, the individual member will have the opportunity not only to discuss with fellow members the needs of his own segment of plastics but also to discuss his problems with experts in the industry. Invitations and complete agendas for each PAG meeting will be mailed shortly after Christmas to each member who has indicated his interest in the PAG survey late last summer.

In the area of PAG accomplishments in 1960, it is with great satisfaction that the PAGs view the program of the 17th ANTEC. In the vital technical programming activity they have played a greater role than ever before. Each Group has had the opportunity to solicit actively papers for inclusion in the program and to review and aid in paper selection.

In the future, PAGs will exert an even greater influence on the ANTEC program through the medium of the new SPE Technical Program Committee. With direct representation in both developing the program and selecting papers, a major share of the program burden will rest upon the Professional Activity Groups.

All of you are familiar with the general accomplishments of PAGs in 1960 including the PAG brochure and membership survey, organization of new Groups for both Blow Molding and Color, this new feature in the Journal, a revised PAG Manual of Procedures and increased PAG participation in RETECS. Just how many of you are familiar with the specific accomplishments of your own PAG? For an up-to-date progress report on these activities and to help guide the future of your chosen Group, attend its Annual Meeting at ANTEC.

Hope to see you there.

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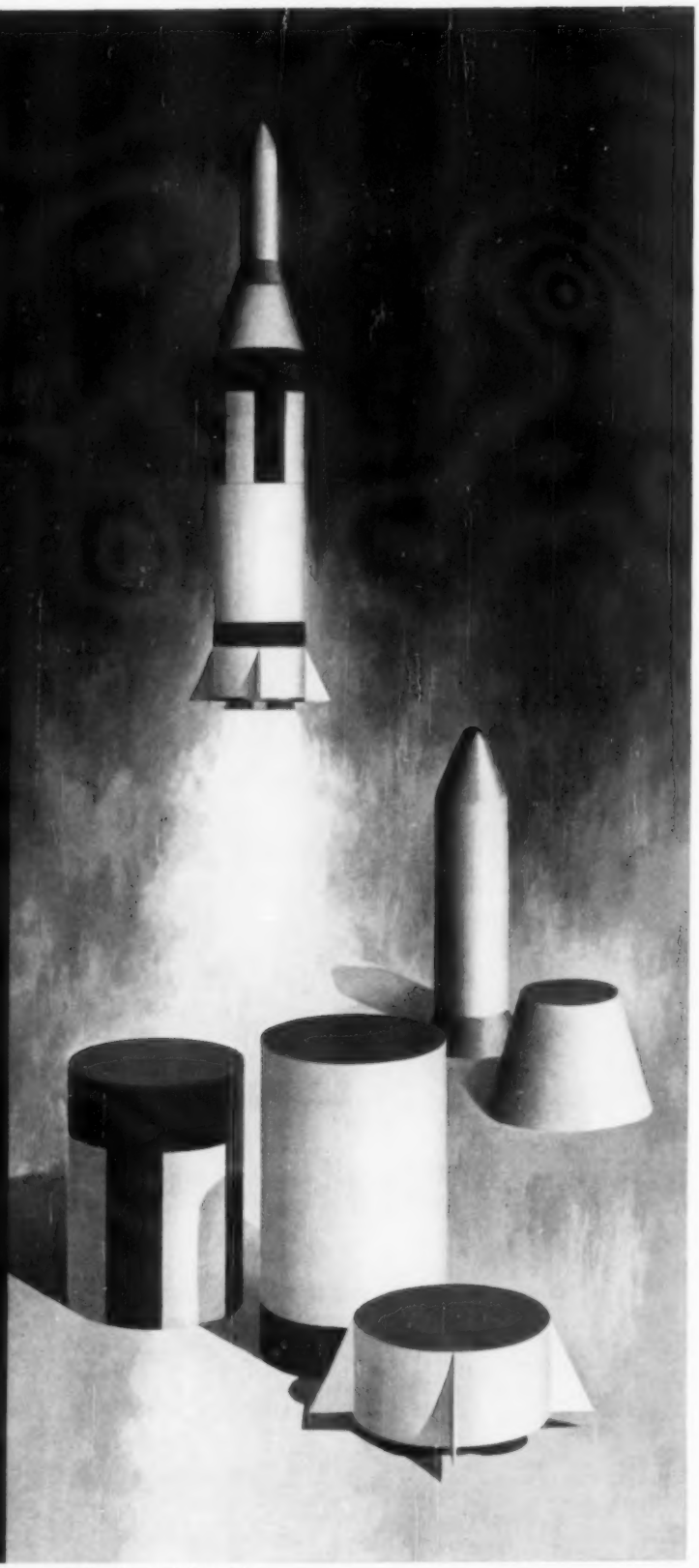


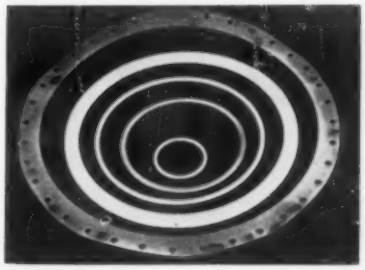
Engineers, scientists—investigate outstanding opportunities at Aerojet

This month marks the beginning of a new service for the reader of the SPE Journal —a new materials and equipment department. So that you can get the information you want in the shortest possible time, we suggest you write directly to the company address listed at the end of each new product item.

New Materials and Equipment

MATERIALS AND APPLICATIONS

Heat and Corrosion Resistant Plastic



Allied Chemical announces its Halon fluorohalocarbon molding and extrusion compounds, serviceable from —320°F to 350°F or 390°F, depending on type. They are FDA approved for food-contact use, impact and abrasion resistant, and show good electrical properties. Chemical and solvent resistance is excellent, reports the manufacturer. Literature available. *Dept. SPE,* **Plastics & Coal Chemicals Division, Allied Chemical Corp., 40 Rector St., New York 6, N. Y.**

Flexible Plastic Pipe

Republic Steel's "SRK" plastic pipe, made of ABS (acrylonitrile-butadiene-styrene) resin is well suited for nurseries and farms. It may be turned, looped or woven between obstacles, is easy to install by solvent welding technique. Resistance to chemical fertilizers, other soil agents is reported to be good. *Dept. SPE,* **Republic Steel Corp., 1441 Republic Building, Cleveland 1, Ohio.**

Flexible Foam Adhesive

A neoprene base clear adhesive for polyurethane foams utilizing a delayed setting time is offered by United States Rubber Co. With only slight pressure during joining, the bond is dimple free and stronger than the parent foam material. The product is known as M-6479 Adhesive. *Dept. SPE,* **Public Relations, United States Rubber Co., 1230 Avenue of the Americas, New York 20, N. Y.**

Abrasion Resistant Urethane Coating

A sealer for wooden floors made from Spenkel F77-60MS urethane coating resin resists severe abrasion (such as roller skates), water, salt and sand. Spencer Kellogg offers this and many other urethane coating resins, together with formulating information. *Dept. SPE,* **Spencer Kellogg and Sons, Inc., P.O. Box 989, Buffalo 5, N. Y.**

Stabilized Stannous Octoate Catalyst

A form of stannous octoate catalyst for urethane foams stabilized to minimize loss of activity during contact with air is offered by Witco. A technical service bulletin comparing Witco Fomrez C-2 with other stannous octoate catalysts is available. *Dept. SPE,* **Witco Chemical Co., 122 E. 42 St., New York 17, N. Y.**

Glass Fiber Surfacing Mat

Reinforced plastics molders are offered a new surfacing mat which offers the molding characteristics of a veil, but handles and separates like a mat. Type 500-H Surfacing Mat has a polyester binder and silane finish, is available in 5, 10, 15, 20, and 30 mil thicknesses. *Dept. SPE,* **Attention Mr. W. B. Bateman, Famco, Inc., 6200 Strawberry Lane, Louisville, Ky.**

Sterilizable Polyethylene

Parts which won't sag after repeated washing and sterilizing may be extruded from Dow Polyethylene 663E, a medium density polyethylene suitable for food contact applications. Plastic drink sippers for sickroom use molded from this material are safe from breaking or chipping, and will snap back after bending. *Dept. SPE,* **Public Relations, Dow Chemical Co., Midland, Mich.**

PVC Stabilizer

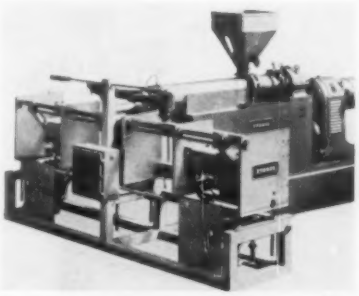
A new cadmium-barium liquid stabilizer for all forms of poly(vinylchloride) offers good long term heat stability without sacrificing initial color. Information and samples of Metasap AB-62 are available. *Dept. SPE,* **Metasap Division, Nopco Chemical Co., 60 Park Place, Newark, N. J.**

Sustained Heat Polypropylene

AviSun Corp. is introducing two new grades of polypropylene for extrusion and injection molding. These polymers are recommended for hot water-detergent, chemical, electrical and automotive applications where high temperatures exist for extended periods of time. Extrusion grade #1041 and injection molding grade #1044 are approved by the National Sanitation Foundation for all potable water applications, and #1044 carries Underwriters Laboratories approvals for high temperature electronic service. *Dept. SPE,* **Attn.: J. C. Warren, Polymer Sales Manager, AviSun Corp., 1345 Chestnut St., Philadelphia, Pa.**

EQUIPMENT

"Five Gallon" Blow Molder



F. J. Stokes is introducing a new dual manifold extrusion blow molding machine with optional accumulator, capable of molding sizes equivalent to a five gallon container of polyethylene, poly-

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Efficiency Level to obtain equal moduli (parts per hundred)	39	52	54	53
Low Temperature Flexibility Tf°C @ 135,000 psi	-36.6	-22.8	-24.8	-15.7

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styrene and other plastics. Providing 550 square inches of mold area at each station and 28 inches of clearance to open molds, the machine uses the output of a 3½ inch extruder. Sold alone or with extruder. *Dept. SPE,* **Attn. Victor N. Musmanno, F. J. Stokes Corp., 5500 Tabor Road, Philadelphia 20, Pa.**

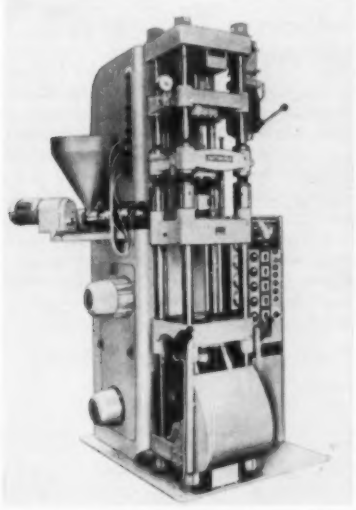
Air Comparison Pycnometer

Beckman Model 930 Air Comparison Pycnometer will measure solids volume of granular or porous materials for density or porosity determinations. This instrument operates by comparing pressure rise in two compression chambers, one containing the sample, thus eliminating temperature control and direct gas pressure reading problems. The method is simple, quick and not complicated by bubble, wetting and flotation problems of liquid immersion systems. Bulletin No. 786 available. *Dept. SPE,* **Technical Information, Beckman Scientific and Process Instruments Division, Fullerton, California.**

Internal Mixer

An interlocking rotor internal mixer long used in England is now manufactured in the U. S. as the Adamson-Shaw Internal Mixer. Rapid mixing, kneading action and good cooling are advantages of this machine. Literature available. *Dept. SPE,* **Attn. Mr. John Drew, Sales Dept., Adamson United Co., 430 Carroll St., Akron, Ohio.**

Vertical Injection Molding Machine



A new vertical injection molding machine occupying only a 4 by 5 foot floor space has been introduced from Germany. Injection capacity is 3½ ounces, maximum plasticizing capacity, 27 pounds per hour, maximum shot sequence, 600 per hour. The Model BSM-40PV machine is designed for molding with metal inserts. A two button mold closing control assures

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Write for Data Sheet or Consult
Chemical Materials Catalog
Page 179 for further data.

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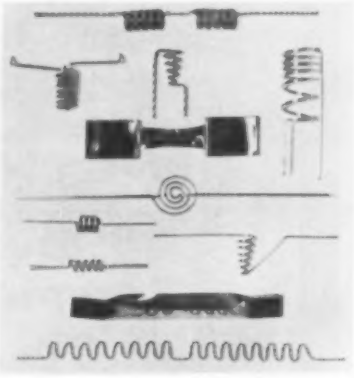
operator safety, while the molding sequence is automatically controlled. *Dept. SPE*, **Battenfeld Corp. of America, 959 West Grace St., Chicago 13, Ill.**

Automatic Vacuum Forming Machine

A versatile automatic vacuum forming machine (Model V) will do vacuum forming, vacuum drape forming and skin packaging on a 24-hour basis. Short runs can be done by manual operation; roll and sheet feeders operate for automatic runs. *Dept. SPE*, **Pacific Plastic Machinery, Inc., 3443 S. Lawndale, Chicago 23, Ill.**

Vacuum Metalizing Filaments and Boats



A new complete line of tungsten, tantalum and molybdenum filaments and boats for high vacuum metalizing evaporation sources is now available. Parts are stress relieved for long life, and are made of high purity metals. *Dept. SPE*, **Electronics Division of Allen-Jones, Inc., 1345 Gaylords Ave., Long Beach, Calif.**

Transistorized Temperature Control

A new line of heavy duty millivolt pyrometer controllers featuring solid state control units gives plus or minus one percent accuracy within an ambient range of 50 to 120°F. These controller units are adaptable to other electrically measured quantities, such as pressure and speed. A galvanometer sensing unit transmits information to the control amplifier by means of a photocell, avoiding mechanical interference with the galvanometer. *Dept. SPE*, **Daystrom Inc., Weston Instruments Division, 614 Frelinghuysen Ave., Newark 12, N. J.**

MANUFACTURERS' LITERATURE

Fiber Glass Textile Yarn

A 12-page brochure describes the manufacture and properties of eight types of fiber glass yarns and textile fibers. Properties of other natural and synthetic fibers are compared with glass, and fiber nomenclature is explained. *Dept. SPE*, **Johns-Manville Fiber Glass, 22 East 40th Street, New York 16, N. Y.**

Morflex Specialty Plasticizers (Data Sheet No. 556)

This set of data sheets lists the properties and plasticizing qualities of 12 ester-type plasticizers for vinyl films. Specifications and test methods are described. *Dept. SPE*, **Charles Pfizer & Co., Inc., Chemical Div., 630 Flushing Ave., Bklyn., 6, N. Y.**

Butyrate for Outdoor Signs

A 46-page illustrated booklet will serve as a manual for fabricators and sign designers using cellulose acetate-butyrate sheet. Detailed design, fabrication and trouble shooting instructions are given, together with a list of materials and equipment suppliers. *Dept. SPE*, **Eastman Chemical Products, Inc., Kingsport, Tenn.**

Standard Mold Bases and Moldmakers Supplies

Detroit Mold Engineering has issued a 240-page catalog describing a wide variety of mold bases and moldmakers tools and supplies. Plastic molders using all processes, mold designers and moldmakers will find this book useful. A considerable amount of engineering data is included. *Dept. SPE*, **Detroit Mold Engineering Co., 6686 E. McNichols Road, Detroit 12, Mich.**

Adhesives, Coatings and Sealers

A 12-page booklet describes numerous uses and appropriate formulations of adhesives available from Minnesota Mining. Related coatings and sealers are similarly listed. A cross reference index gives a quick lead to solutions of many plastic bonding problems. *Dept. SPE*, **Attention G. W. Crain, Adhesives, Coatings and Sealers Division, Minnesota Mining and Manufacturing Co., 900 Bush Ave., St. Paul 6, Minn.**

Diallyl Phthalate Molding Materials

A 28-page booklet describes the properties and fabrication instructions for diallyl phthalate molding resin. Chemical, electrical, biological and general physical properties are listed. Applications of the resin in molded parts and coatings are described. *Dept. SPE*, **Food Machinery and Chemical Corp., Chemicals and Plastic Division, 161 East 41st St., New York 17, N. Y.**

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PLASTICS AROUND THE WORLD

This month's column has been made possible through the contributions of these abstracters:
Alexander Baczewski (L'Officiel des Matières Plastiques)
Leonard S. Buchoff (Materials in Design Engineering)
Walter A. Gammel, Sr. (Rubber and Plastics Age)
Hans Mayer (Industrie des Plastiques Modernes)
Evert A. Mol (British Plastics)
Samuel S. Oleesky (Plastics and Practical Plastics)
Geza Gruenwald (Kunstsoffe-Rundshau)
John J. Shay (Electrical Manufacturing)
George Lubin (Russian Plastics)

Germany

KUNSTSTOFFE-RUNDSCHAU, 7

AUGUST 1960

Plastic Laminates on Sheet Metals—pp 380-383

Vinyl-laminated metal sheets are manufactured in Germany from deep-draw steel (.012 to .080 inch) and aluminum sheets (.020 to .060 inch). An adhesive is spread on the sanded metal surface and the 6 to 12 mils vinyl film laminated onto it under heat and pressure.

Bending, beading and deep drawing may be accomplished successfully independent of which side is forced under tension. It is claimed that, up to the total elongation of the metal, the surface design and color of the plastic is not impaired.

Though spot and seam welding may be accomplished after removal of the plastic layer, the use of specially designed electrodes for welding the metal from the back side is recommended.

A few tables underline the good chemical resistance and adhesion of the plastic layer. Pictures show applications of this material, e.g., for appliances, office furniture and structural sheets. One square foot of a 40-mil thick vinyl-steel laminate sells for $0.43-.54.

SEPTEMBER 1960

Blow Molding of Polyethylene Parts—pp 421-426

A comprehensive list of literature and patents and many drawings add to the completeness in the description of all, more or less, useful processes for blow molding polyethylene articles. Based on the author's background, the application of high density polyethylene (and polypropylene) is discussed more thoroughly. Users of this material will find many of the recommendations valuable, e.g., for avoiding weld lines by forcing the material to bypass a protruding circular fin around the mandrel, for improving the strength of the bottom part by flattening the pinch-off edge, for compromising between appearance and environmental stress cracking, and for meeting the higher mold shrinkage of high density material by several process changes. At the end, the not too popular method of expending hot injection molded blanks is discussed.

Improvement of Adhesion of Some Bonding Agents by Addition of Isocyanate—pp 389-390

The adhesive strengths of rubber-metal, rubber wood, and PVC-metal-glueings are considerably increased by additions of triisothianate analogous good effects are obtained with polyamide-metal compounds. Strength factors and working prescriptions are indicated.

Viscosity Measurements of Solutions as a Function of Pressure and Molecular Weight of the Substance Solved—pp 391-392

Unfractionated polystyrenes as well as fractions of polystyrenes both with different molecular weights were tested within the pressure limits of 1-5000 kp, cm^{-2} at 30°C in a falling-ball viscometry according to the principle of Hoppler. The dependences of the viscosity on molecular weight and pressure are plotted.

Tinting of Polytetrafluorethylene (PTFE) Using Radiation-Chemical Graft Copolymerization—pp 393-395

Radiation-chemical grafting by slightly grafted polymers is shown to be able to produce well colourable polytetrafluorethylene films without doing harm to mechanical properties of the film. Comments given by the authors include grafting methods, monomers, kinetics, tinting of films.

Great Britain

PLASTICS

AUGUST 1960

Machines for Industry—pp 310-314

This is a very interesting feature of "Plastics", in that it describes commercial machines and their operation. The particular machines discussed in the August issue are the Battenfeld BSM VP 160/350 Injection Machine and the Stokes 800 Automatic Press.

It is difficult, in presenting such material, to avoid making the presentation a glorified "commercial" or expansion of the vendor's brochure. The editors of "Plastics" have managed to avoid this pitfall. They dispassionately describe the construction of each machine, show its operating theory, and give clear line drawings of the assemblies. Specifications are listed, and the reader feels that he has learned something, rather than that he has been exposed to a sales "pitch".

The Microscopic Examination of Rubbers, Plastics and Fillers—pp 329-332

Some basic methods of electron-microscopy in the study of high polymers are described. Some specialized optical methods are also discussed.

A few of the techniques are well known, but some have been developed at the National College of Rubber Technology for use with specific materials. Not all methods are of general application, but a study of them will certainly be of interest to those in the field.

General Method for the Estimation of Antioxidants in Polythene—pp 319-321

In essence, the paper describes a method of evaluating the effect of the antioxidants on ferric ions in a ferric chloride solution, reducing them to ferrous ions which can then be estimated calorimetrically

by the use of 2,2'-dipyridyl, which forms a red complex with ferrous ions.

The discussion describes in detail the test method, including necessary materials and equipment, procedure, verification, and possible causes of deviation. It is logical, succinct, and certainly a contribution of value.

Window on Russian Research—pp 315-318

Dr. Gordon presents to the British plastics industry a summary of papers presented at the International Symposium of Macromolecular Chemistry, held in Moscow on 14-18 June 1960. While the summaries are necessarily brief, their scope is such as to be of interest to plastics engineers in all phases of the industry.

Titles include the following:

- Vinyl polymerization kinetics
- Emulsion and interfacial polymerization
- Solid-state polymerization
- Stereospecific polymerization
- Cyclopolymerization, and a new route to polyvinylacetals
- Unsaturated polyester resins
- Degradation studies
- Graft polymers and radiation cross-linking
- Extremes of stability and instability
- Condensation polymers and "living" polymers
- Ion exchange and redox resins; polyelectrolytes; inorganic polymers.

In view of the fact that the author has already condensed these papers, it is obviously impossible to cover them adequately for these abstracts. However, it may be stated that the summaries given are adequate for providing, as the title implies, a good, hard look at the state of the art in Russia today.

SEPTEMBER 1960

Machinery and Production Requirements for Plastics in the Soviet Union

In this reprint from the Soviet magazine "Plastmassi", an unnamed technologist discusses frankly the current state of the Soviet plastics industry.

A complete summary of this article is difficult to prepare, because of the terse manner in which it is presented. However, despite the conciseness, the discerning reader may read between the lines and deduce that the Russians are in the same position that we in the U. S. found ourselves about ten or fifteen years ago. Typical quotations are: "The number of such (injection molding) machines must be increased between 10 and 12 times by 1965", and ". . . efforts are being made to design multicavity injection moulds." In connection with glass-reinforced plastics, they say: "This is a new branch of technology."

If the indications of this article are to be believed, the Soviet Union will not offer serious competition in world markets during 1961—and probably not in 1966, either.

Epoxide Tools—An Appraisal

This is another survey paper which assembles current knowledge and ties it into a single "ball of wax". Except for a brief prognosis of the future, it serves only to give a relatively new slant on, and to refresh memories in a few areas which may have been overlooked.

An Evaluation of Some Low Density Sandwich Laminates

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aspects of plastics sandwich construction. The author includes core materials of foams, honeycombs, wood, and the so-called "compounded foams." He discusses preparation of sandwiches for testing; test methods; results of tests; flexural fatigue; strength-weight ratio; physical properties; and other topics of diverse interest.

True, this paper adds little, if anything, to the state of the art. However, it serves a purpose, in that it summarizes what has been done to date and provides a new slant on the subject.

RUBBER AND PLASTICS AGE

JULY 1960

Plastics Institutes in Leningrad and Moscow—pp 790-793

The Scientific Research Institute of Polymerizing Plastics in Leningrad investigates only polymers which are produced by true polymerization reactions. Condensation polymers, such as the polyamides, are the subject of investigation by the Moscow Institute, the other institute which studies the practical aspects of plastics.

The 100,000 sq. ft. Institute at Leningrad employs about 450 for servicing, 300 technicians, and 750 on experimental work in industry. Major study areas now are (1) the polyolefins, (2) polystyrenes and their derivatives, (3) polyvinyl acetate and its derivatives, and (4) fluorine organic plastics. They have at least three (3) electron microscopes including a Japanese. The Soviets claim to be developing one of even greater magnifying power.

The Institute at Moscow employs about 1600 of whom ¼ are qualified engineers or scientists. Work is being conducted on the centrifugal casting of nylon for such items as gear wheels. One photo shows a Rand gun being used for laying polyester-glass. Some elegant testing equipment was noted. (Article illustrated with 8 photos)

Instrument Exhibition in Moscow—p 799

Forty-one members of Scientific Instrument Manufacturers Association demonstrated their latest ideas and equipment in largest foreign exhibit—Moscow. Valued at about £ 250,000 (English pounds sterling), 95% of instruments were sold from the stand.

Items sold included double beam recording infra-red spectrometer, x-ray diffractometer, direct reading emission spectrograph, argon chromatograph, a nondestructive ultrasonic flaw detector, continuous Beta-gauge thickness tester, punch card analyser, and a new melting-point apparatus.

Visit to Pernis—p 819

Shell refinery at Pernis, to produce styrene-butadiene synthetic rubber, opened June 24, 1960. Has capacity of 60,000 tons per annum.

In the copolymerization plant, all chemicals (20) required are added automatically. (Must have "feed-back" for such control).

BRITISH PLASTICS

SEPTEMBER 1960

Recent Experience with Polycarbonates—pp 406-409

Polycarbonates based on bisphenol A are outstanding in the relatively small effect that temperature has on both mechanical and electrical properties. The article gives many examples of this as observed on Makrolon, the German counterpart of Lexan. In addition, the processing of the material is described in some detail, mostly as it refers to molding and extrusion. Ways and means to improve the quality of finished productions are given.

United States

MATERIALS IN DESIGN ENGINEERING

JUNE 1960

"Appliances: What Materials are Next?"—pp 121-130

Glass reinforced polyesters are not feasible for use as housings because of their high price, discoloration on aging and difficulties in mass production. Formed polystyrene sheets are widely used as door liners. There is a great need for heat resistant, non-flammable decorative plastic. Polypropylene and Hypalon are used in washing machines because of their chemical resistance. Nylon may be replaced by Delrin in some bearing applications. Vinyl-metal laminates are used as decorative covers. Epoxy and acrylic coatings are used widely. Urethane foams blown with Freon are becoming popular as insulation.

Potting and Encapsulating Materials—pp 166-170

Application of electrical castings using styrene polyesters, epoxies, polyurethane, silicone rubbers, polyvinyl chloride and polysulfide rubbers are discussed.

ELECTRICAL MANUFACTURING

OCTOBER 1960

Properties of Polyester-Resin Glass-Fiber Banding Rings—(Author—M. M. Felger)

Resin-bonded glass fibers are replacing steel wire as banding structures in rotating electrical equipment. Dimensional changes in both bar and band structures during the polyester resin cure have been measured and found to be very small. Flexural and tensile moduli, tensile strength and the effect of thermal aging were determined for four available constructions, assembled in a procedure similar to that used in a production operation.

MATERIALS IN DESIGN ENGINEERING

JULY, 1960

ABS Plastics Are Low Cost, Tough, Resistant, Moldable

ABS plastics have toughness, wide temperature range, excellent resistance to chemicals and weathering, good electrical insulating properties and good moldability. Five grades varying in impact and heat resistance are available. Charts and graphs available.

How Radiation Affects Engineering Materials

Urethane rubber has the best radiation resistance of the elastomers listed. Natural rubber is next followed by SBR acrylic, nitrite, neoprene, silicone, fluoroelastomers, polysulfide and butyl rubbers. Radiation resistance can be improved by the use of fillers, radiation-resistant resins and antirads.

Plastics with the highest radiation resistance include polystyrene, mineral-filled phenolics and polyesters, phenolic laminates, polyethylene, terephthalate, polyvinyl chloride, epoxies and glass reinforced silicones. Plastics with intermediate radiation resistance include melamine-formaldehyde. unfilled phenolics and urea-formaldehyde. Poorest radiation stability

is exhibited by the cellulosics, polyamides, Teflon and unfilled polyesters and silicones.

AUGUST 1960

Filament Wound Reinforced Plastics

Conventional E glass and epoxy resins are usually used to produce filament wound parts. This process produces a part of maximum structural efficiency for putting the strength where you need it. Pre-oriented prepreg shows promise where complex shapes are encountered, yet maximum strength and rigidity are required.

Filament winding is done by winding with roving wet with resin, B-staged roving onto a heated mandrel, or with dry roving, impregnated after winding.

Methods used by one company for evaluating materials for filament winding include an initial screening of the epoxy resin, strength tests on unidirectional specimens, burst strength on test cylinders and evaluation of finished parts.

Data is given on the effect of winding tension, roving end count and resin content on the mechanical properties of filament wound structures.

France

L'OFFICIEL DES MATIERES PLASTIQUES

OCTOBER 1960

Polymers Containing Silicon—pp 716-732

A list of 415 French patents from 1945 to 1947.

Plastics in Textiles and Leather—pp 729-734

An annotated list of 201 French patents filed between 1942 and 1955 and published recently.

Non-Supported Films—pp 757-761

Bars containing compounds of Radium or Polonium are used for the dissipation of static charges arising while plastic sheeting is calendered. Internal tensions are eliminated by floating the film upon a heated liquid after emerging from the calender. Recently extruders have been built in France which manufacture 6 feet widths of 5 mil polyethylene. Polycaprolactam films are stretch oriented in order to improve their mechanical properties.

27 references are listed.

INDUSTRIE DES PLASTIQUES MODERNES

OCTOBER 1960

Observations on the Rupture of Plastics

This article explains the mechanics of rupture of thermosetting or rigid thermoplastic molded specimens as they occur under exposure to impact or progressive bending. On the basis of tests the standard methods of testing (Charpy and Yzod) are developed.

Utilization of Allyl in a Resin, Suitable for the Molding of Optical Objects.

Diethylene-glycol bis-allyl carbonate is a formulation for a resin which will polymerize into a transparent, chemical resistant and scratch resistant article of high optical qualities. The tooling for the production of lenses from this material and the molding procedure recommended are described with a discussion of the optical characteristics of the finished product.

Australia and New Zealand

PRACTICAL PLASTICS

AUGUST 1960

Trends of Glass Reinforced Plastics in the Automotive Field

An excellent and concise (4-page) summary of the industry in Australia and New Zealand. Although frequent reference is made to U. S. counterparts of Anzac items, the many applications illustrated in the article as examples of their own ingenuity should demonstrate to some self-satisfied local engineers and production men that we do not have an exclusive franchise on technical brains in the U.S.

Plastic Sheetings Limited

This feature article was apparently designed to discuss the construction of a new calendering plant in New South Wales. However, instead of the usual "blurb" type of publicity release, it develops into a well-written description of the plant facilities, production technology, materials and their properties, applications for the various materials, etc. A two-page flow diagram is included, enabling those outside of this branch of the industry to understand not only how the plant operates, but actually what the whole field covers.

Russia

RUSSIAN PLASTICS

AUGUST 1960

Russian Polymer Research—pp 907-911

The Karpov Research Institute, Moscow, is doing fine work on gamma radiation. These are two Cobalt 60 sources: one of 13,000 Curies and one of 40,000. There is also a 2.5 million volt Van der Graaff accelerator.

At the Institute of Elemento-Organic Compounds, studies have been made including those on interfacial polycondensation reactions—the interface being the reaction site—with polyamides and polyesters.

The Russians are working on resins compounded with highly refined fibrous potassium titanate as the approach to high temperature plastics.

During the Macromolecular Symposium in June, M. L. Huggins (U.S.A.) presented a theoretical paper on the mechanism of Ziegler catalysis. He suggested that addition of monomer occurs by a coordinated ionic mechanism with a shift of the growing polymer molecule with each monomer addition

SEPTEMBER 1960

PTFE and the Processing of Coagulated Dispersion Polymers

PTFE is a thermoplastic with so high a melt viscosity it will not flow by conventional means nor by compression or transfer molding. The polymer is prepared in granular and dispersion forms. The latter has better properties but require specialized processing techniques.

Screw extruders are not used, but ram extruders are. Poly TFE extrusions are 3 times the length of the final desired product because of the volume reduction of extrusion composition to finished billet. Extrusion pressures range from 2,000 to 10,000 psi. Special mandrels are required for wire covering and tubes since, once the material has started to flow into the die, it must not be divided or it will not join up again satisfactorily. Tape is made by calendering extruded rod which is not dried or sintered.

Except for special purposes the extruded PTFE material is sintered at 380°C following drying to remove lubricants which were added to aid processing.

SECTION NEWS

Newark

Plastics in Construction

R. E. Christensen (Union Carbide Plastics Co.)

The Newark Section met at the Military Park Hotel in Newark on November 9.

The first speaker, Mr. G. Richard Franson of Dow Chemical Co., Midland, Michigan, gave a comprehensive discussion of plastics in the building industry. He described the wide range of materials and their applications in housing. Examples included the use of plastic materials in dry wall construction, roofs, and flashing. It was pointed out that a large potential exists for the use of plastics in the building industry However, antiquated building codes in many areas of the country still exclude the use of plastics in proven applications.

The second speaker, Mr. Otto H. Fenner of Monsanto Chemical Co., St. Louis, Missouri, described an accelerated test procedure for the evaluation of fiber-reinforced resin equipment in the chemical industry.

RETEC: "Blow Molding Comes of Age"

R. E. Christensen (Union Carbide Plastics Co.)

Judging by the record-breaking attendance at Newark Section's RETEC on November 18, 1960, at the Essex Hotel in Newark, blow molding has indeed come of age. A total of 679 members and guests registered, a new all-time high for RETECs. The expectations of the attendees, who were listed from as far away as Canada, Holland, and Germany, were well rewarded by an outstanding program.

The collection of papers presented could well serve as a complete handbook on blow molding. Every aspect of the science and the art was presented, including the history of blow molding, the markets and applications, the characteristics of the materials used, the types of processes, including machines, molds, and techniques involved, and the very critical patent situation.

Among the many highlights of the full program of fourteen papers was a Machinery Panel which read like a "Who's Who" of American Blow Molding Equipment Manufacturers. This panel discussed the different types of equipment commercially available. Also, an excellent and very comprehensive discussion of the "Patent Problems Facing U. S. Blow Molders" was presented by Dr. W. A. Schaich, Patent Counselor for Owens-Illinois. Much interest was shown in an eye-catching exhibit of blow molded pieces of all types prepared by the Celanese Plastics Co.

The luncheon speaker was Thomas H. Risk of the Engineering and Research Staff, Ford Motor Co., Dearborn, Mich. Mr. Risk presented a timely picture of the "Automotive Uses and Requirements of Plastics." He pointed out the sizable increase in the use of plastics in automobiles from less than five pounds per car in 1940 to almost twenty-one pounds in 1960, with the anticipated use of about forty-five pounds per car in 1965. This healthy increase is the result of the continual introduction of new plastic materials, reductions in price while other materials go up, and better understanding of properties, methods of fabrication, and end use. Mr. Risk stated that present materials are adequate for their current applications, but that the next step into additional automotive components requires improved physical and mechanical properties over the variety of temperatures, from −40 to 250°F., encountered in automobiles.

Al Spaak, Section President and Master of Ceremonies for the luncheon, introduced the Honorable R. A. McKinley, Deputy Mayor of Newark, who welcomed the Society of Plastics Engineers on behalf of Mayor Leo P. Carlin. In conjunction with the Newark Section's RETEC, Mayor Carlin proclaimed the week following the RETEC as Plastics Week in the City of Newark, and a large banner was mounted at City Hall to welcome the SPE members.

George W. Martin, President of SPE International, spoke at the luncheon on the educational program of SPE, emphasizing the increasing role of the schools in providing training. He cited the Newark Section for the example which its educational program has set for other sections.

The RETEC Committee is congratulated for the outstanding program. R. H. Hoehn was Chairman of the Conference and of the RETEC Committee, which included: V. Q. Merrill, Program Chairman; S. S. Bodner, House Chairman; D. A. Jones, Registration Chairman; R. Bostwick, Conference Treasurer; E. J. Csaszar, Publicity Chairman; K. G. Smack, Printing Chairman, and A. S. Spaak, Section President. Their success was attested to by the large attendance and sustained interest of the audience throughout the conference.

Members of the Machinery Panel at the Newark Section's RETEC on blow molding were: G. Tanner of Auto-Blow Corp., Moderator, E. P. Moslo of Moslo Machinery Co., L. J. Kovach of Modern Plastic Machinery Corp., G. H. Pickering of Air-Formed Products Corp., D. Rainville of The Rainville Co., and I. Thomas of Newark Die Co.

George W. Martin, President of SPE International, addresses the RETEC luncheon as Albert S. Spaak, Newark Section President, Thomas H. Risk of Ford Motor Co., the luncheon speaker, and Robert H. Hoehn, RETEC Chairman, listen.

Southern California

Plastics in Missiles

I. M. Zelman (American Reinforced Plastics Co.)

W. L. Mackie of the Pacific Missile Range at Point Mugu, California, makes a point on the use of plastics in missiles at the monthly meeting of the Southern California Section on October 6 at the Rodger Young Auditorium in Los Angeles. Mr. Mackie stressed the contribution of high temperature plastics to the missile program, and the major role which plastics are destined to play in the missiles of the future.

Eastern New England

Epoxies and Elastomers

D. V. Rosato (Raytheon)

The October meeting, the first of the season after the September RETEC featured two speakers.

The first speaker, William Ibsen, Ciba Products Corporation gave a talk on Recent Developments in Epoxies.

It was a survey of some of the new epoxy resins, reactive diluents, and hardening systems. Investigation and discussion of the possible applications of these new products followed. Finally, various avenues of research and the type of products expected in the near future were discussed.

The second speaker was Peter Virtue of Cabot Corp., Minerals & Chemicals Div. who discussed **Wollastonite—An Extender for Polystyrene.**

He pointed out that wollastonite is a mineral form of calcium silicate at Cabot mines and processed in upper state New York on Lake Champlain. For years it has been used as a functional extender for decorative coatings and thermosetting plastics. It is also a basic raw material in the manufacture of ceramics.

The meeting of November 22, 1960, featured a rather complete story on elastomers presented by Harry Fishman and Richard W. Ward of E. I. du Pont de Nemours & Company, Inc., Elastomer Chemicals Dept.

They presented a general discussion on "Elastomers—Their Properties and Uses" with specific emphasis on the DuPont Elastomers—Neoprene, Hypalon Synthetic Rubber, Adiprene Urethane Rubber, Viton Fluoroelastomer, and a related family of materials. Urethane foams based on Hylene Organic Isocyanates were also reviewed.

Rochester

Polyurethane Foams

John T. Bent (Eastman Chemical Products)

Sixty-four members and guests heard Mr. William Monohan, President of Rochester Urethanes Corp., discuss rigid, semi-rigid and foam polyurethanes at a dinner meeting at Logan's, the regular meeting place. The discussion was climaxed by a foaming demonstration of an ether type polyurethane. Mr. Monohan stressed the amazing growth of the polyurethanes and forecast an even more rapid growth during the next five years.

Milwaukee

Missiles in Action

C. H. Strong (Union Carbide Plastics)

Milwaukee Section held its second meeting on October 11 with a large attendance of 65 members and guests. They heard John Malinek of A. C. Spark Plug discuss "Missiles in Action." Three movies, showing laboratory development, parts production and the function of the parts were presented, followed by a question period.

Ontario

Automation RETEC

Harold A. Shure (Naugatuck Chemical Co., Ltd.)

The November 7 Regional Technical Conference (RETEC) on "Automation in Injection and Compression Molding" drew 210 registrants from U. S., Canada and England for two concurrent sessions.

Plastics Replace Metals

The November 17th meeting in Toronto was on "Replacement of Metal Parts with Plastics Materials". Mr. Robert L. Gardner, Head Technical Service Representative of Rohm & Haas Co. of Canada Ltd. primarily discussed impact modified acrylic molding compounds (Implex) for such industrial applications as automotive parts, shoe heels, vending machines, marine and textile industries. Acrylic (Plexiglas) in the same fields and the molding of mixtures of Implex and Plexiglas was covered.

Mr. Gardner was introduced by Mr. A. T. Orr of Rohm & Haas Co. of Canada Ltd. and his talk was appreciated by the 82 persons attending the meeting.

Ontario RETEC Committee Chairmen and visiting SPE Officers get together for traditional photo on November 7. Front row (from l. to r.) Harry E. Watson, Section President; George W. Martin, SPE President; and J. Mackenzie ("Mac") Lees, RETEC Chairman. Standing (from l. to r.) Maurice F. Malone, SPE Executive Committee and 1961 Secretary-elect; Harold Hillsdon, Program Co-Chairman; Thomas A. Bissell, SPE Executive Secretary; and Lloyd Leadbeater, Program Co-Chairman.

Connecticut

Electric Discharge Machining

K. G. Clarke (E. I. du Pont Co.)

"New products need new types of tooling technique" was the theme of a discussion of the Electric Discharge Machining Method at the monthly meeting held November 11 at the Hotel Barnum in Bridgeport.

Mr. Earl W. Siegel, Senior Engineer, Tool Development Service, General Electric Company, Schenectady, New York, presented a description of this process and its application to a large cross section of molders, tool builders, and design engineers.

The fundamentals of the electric discharge machining techniques were presented in the form of sound motion pictures, along with some slides, and a panel discussion following the completion of the formal discussion. Mr. Siegel had several samples of tools produced by these techniques which had provided the parts buyer with lower cost tooling capable of doing a more efficient job. The simplicity and reliability of this process were emphasized several times during Mr. Siegel's discussion.

Chicago

Mold Pricing

B. F. Brown (Hercules Powder)

Almost 140 section members heard W. J. B. Stokes explain a practical and effective solution to the problem of estimating tool costs. Mr. Stokes is well known as a "down to earth" ANTEC speaker.

John Scharnberg has been appointed program chairman to replace Charles M. Waugh who has been transferred to Wilmington, Delaware.

Baltimore-Washington

Semi-conducting Plastics at Washington

Dr. Fred Leonard (Walter Reed Army Medical Center)

Dr. H. A. Pohl, of Princeton University spoke on the preparation of semiconducting plastics on Tuesday, October 11 at the Thompson Sea Food Restaurant, Bethesda, Maryland.

Dr. Pohl described methods for preparing polymeric materials whose resistivities fall within the region of semiconductors by pyrolysis of carbon base polymers and by synthetic means. The polymers prepared by pyrolysis up to 1200°C in a variety of atmospheres may vary from hard to soft and may be both paramagnetic and diamagnetic. The synthetic polymers may be prepared by condensation of phthalic anhydride with phenols in the presence of zinc chloride. The product is a soft thermoplastic polymer with a resistivity of the order of 10^3 to 10^7 ohm-cm.

Vinyl Foam Extrusion at Baltimore

William M. Miller, Jr. (Hedwin Corp.)

At the October meeting, Robert J. Meyer of B. F. Goodrich Co., Avon Lake, Ohio spoke on "New Dimensions in Cellular Vinyl Processing." He introduced the concept of nitrogen as a low cost filler which does not increase the density of vinyl formulations as do conventional mineral fillers. Blowing agents, extrusion procedures and successful applications were discussed. Other processes where vinyl foams are used include injection molding, blow molding and rotational casting.

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ABOUT MEMBERS

Dr. Jackson

Dale E. Jackson was named Manager of the Plastics Department, Butler Industries Division of Butler Manufacturing Co. Dr. Jackson has been a Senior Research Chemist dealing with product research in plastics since 1957. He graduated from the University of Illinois (PhD, Inorganic chemistry) and worked in the Textile Fibers Department of E. I. duPont de Nemours before joining Butler Industries.

In a realignment of marketing organization, AviSun Corp., has named **E. T. Severs,** formerly Product Manager—Film to be Manager of Market Development. Under Dr. Severs, **Dr. A. Ross Adams** will be responsible for polymer market development and **Ralph M. Winters** for film.

W. J. Belanger has been promoted to Director of Resin Development in the Jones-Dabney Co., a division of Devoe and Raynolds Co., Louisville. Dr. Belanger obtained his B.S. degree from St. Louis University and his Ph.D. from Notre Dame University. He joined Devoe and Raynolds in 1953. Replacing Dr. Belanger as Manager of Jones-Dabney's Plastics Technical Service Laboratory is **W. F. McWhorter,** who graduated from Georgia Tech in 1950 and joined Dabney-Jones in 1956.

R. D. Jackson, President, announced that Plastics Engineering of Hawaii will open a new plant in Honolulu for plastisol coating of large propane tanks for Honolulu Gas Co.'s Isle Gas Service Division.

Clinton J. Starke moved from General Electric Co., Coshocton, Ohio, to a post as plastics engineer in Food Machinery and Chemical Corp.'s Applications Technical Service Laboratory in Baltimore. Mr. Starke is a chemical engineering graduate of the University of Missouri and a Navy veteran.

F. J. Stokes Corporation, Philadelphia, has announced the re-location of the Stokes Chicago Sales Office to larger quarters in the Lincoln Building, 5875 North Lincoln Ave., Chicago, Ill. **Stewart Helliwell,** Midwest Regional Manager, and a member of the Chicago Section of SPE, will be in charge of all Press Division applications.

Poul G. Anderson, who has been studying plastics tool engineering in the U.S., sponsored by the Scandinavian-American Foundation, has recently started his own mold-making business in Copenhagen, Denmark.

Mr. Hadley

Frank E. Hadley has been appointed Chicago Sales Representative of Chemore Corp., U. S. and Canadian representative for Montecatini. Mr. Hadley, a Rutgers University alumnus, was formerly a vice president of Catalin Corp. of America.

Among the new officers of the Plastic Food Container Association are **W. L. Niclaus,** Treasurer, and **C. S. Conklin,** Secretary. Mr. Niclaus is President of Wilpet Tool and Manufacturing Co., Kearny, N. J. Mr. Conklin is General Manager, Plastics Div. of Lily Tulip Corp., New York.

Howard J. Dunn has organized a new company to disperse color in resin vehicles, H. J. Dunn Dispersions, Inc., Box 122, Plainfield, N. J. New grinding methods are expected to lower the cost of color dispersions.

U. S. Industrial Chemicals Co.'s Polymer Service Laboratories announced the promotion of **Alfred B. Zimmerman** to Assistant Group Leader of Applications Development and **Joseph F. Pilaro** to Assistant Group Leader, Customer Service. Dr. Zimmerman, a graduate of Western Kentucky University and Indiana University, has been with USI since 1958. Mr. Pilaro, with USI since 1958, is a graduate of Rensselaer Polytechnic Institute.

Melpar, Inc., electronic manufacturer, has named **Dr. Paul E. Ritt,** formerly Director of the Physical Sciences Laboratory, as its Director of Research.

Northrop Corp. at Hawthorne, Calif. has named **Wesley E. Weber** as a standards engineer in its Nortronics Division. Mr. Weber formerly was connected with Aerojet General Corp.

Kenneth A. Kaufmann joins Rexall Chemical Co. as Assistant Director of Research and Development. He was formerly with Amoco Chemicals Corp., Chicago, in market research and development. Mr. Kaufmann will specialize in sales service and applications research. **Charles G. Kucher** has also joined Rexall at Paramus, N.J., as supervisor of technical service. Mr. Kucher was formerly senior technical service representative in the Eastern sales district of Spencer Chemical Co.

Mr. Woodruff

William K. Woodruff is now Vice President of Convention Sales Corporation, 307 N. Michigan Avenue, Chicago, which offers group meeting facilities to the plastics and other industries. He was formerly district sales manager for Celanese Corp. of America.

John Peterson has been named Director of Industrial Products Sales, Midwest Region, by E. F. Drew, Inc., producer of vegetable oils and fatty acid derivatives. Mr. Peterson, a graduate of M.I.T., was formerly General Sales Manager of Baxter Laboratories.

Mr. Peterson

Among the judges for the SPI's second Bachner Award for Plastics Achievement are **William P. Gobeille,** Manager, Plastics Operations for American Motors and **Hiram McCann,** Editor-in-Chief of Breskin Publications. The award is given to a company which molds, extrudes or pressure or vacuum forms an outstanding plastic product, and a $1,000 prize goes to the employee most responsible for the product.

Firestone Tire & Rubber Co. has opened the first rubber company owned plant making nylon filament for tire cord, with **W. J. Smith** as Plant Manager. Mr. Smith supervises production of both monofilament and multifilament yarn.

Plastics Engineering Sales Co., Jackson Heights, N. Y., owned by **A. J. DeBernardi,** has been appointed consultant in the development of a proprietary plastics program for the Panelyte Division of St. Regis Paper Co. Mr. DeBernardi, a former faculty member of New York City College, has been a plastics consultant since 1946. His company will assist in conception, design, development and marketing of proprietary plastic products.

Loren Patrick Associates have been named sales engineering representatives for Hull Corporation, Hatboro, Penna., vacuum process equipment maker, covering the western states. **Mr. Patrick** is president of this new firm at 1107 S. Fremont St., Alhambra, Calif. He was formerly west coast Manager for F. J. Stokes Corp.

Richard Jacob, executive Vice President of Cadillac Plastic & Chemical Co. announced the opening of new sales offices in Toledo and Dayton, Ohio.

Benjamin M. Walker now heads the Engineering and Development Departments of Information Technology Laboratories, Itek Corp., Waltham, Mass. He was Chief Chemist of Resistoflex Corp.

G. M. Juredine has joined Synthetic Products Co., Cleveland, Ohio as Vice President, Sales. Before coming to Synthetic Products, Mr. Juredine was a division manager with Harshaw Chemical Co. and a consultant to Battelle Memorial Institute.

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The "Mabuhay" A Galaxy boat built by the American Boatbuilding Corp in Warwick, Rhode Island, using PMS polyester color coates.

NEW BOOKS

HANDBOOK OF CHEMISTRY AND PHYSICS

Charles D. Hodgman, Editor in Chief (Chemical Rubber Publishing Co., 3482 pp. $12.00)

This useful and versatile handbook continues to be expanded and brought up to date. The section on plastics, revised in 1958, now includes twenty-nine categories. The Trade Names Table is newly revised and considerably enlarged. New data on organic chemicals include miscibility and sublimation data, as well as the customary enlargement of the Physical Properties Table.

Several new tables on solution properties appear in this issue: Conversion Formulae for Various Expressions of Solution Concentrations, Surface Tensions of Solutes, and Dissociation Constants of Organic Bases in water. Properties tables for such diverse materials as inorganic hydrides, ion exchange resins and chelating agents serve their special needs. Much new material is included in mathematics, metallurgy and even astronautics.

Reviewed by the Editors.

RUNNERLESS MOLDING

Ernest P. Moslo (Reinhold Publishing Corporation, 160 pp. $4.95)

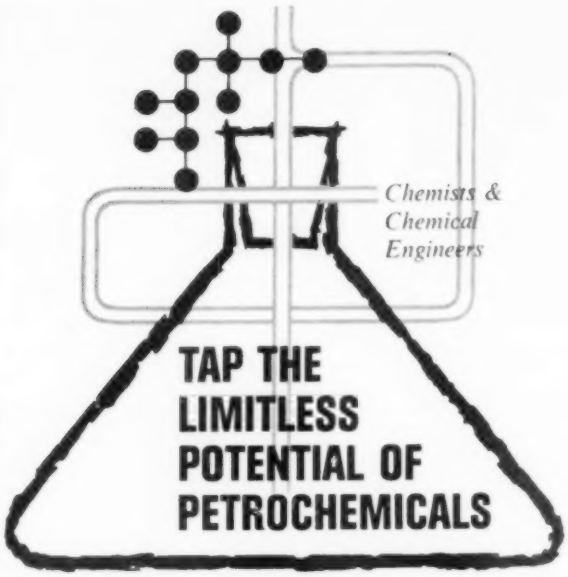
This book provides the reader with a brief insight into the history of the thermoplastic molding industry. The author proceeds from early thermoplastic materials, molds, and machines to the mold design and mold construction in general use today.

Free use of detailed drawings accompany concise descriptions concerning nozzle design for runnerless molds. Topics reviewed include manifold and multiple runner arrangements, thin wall container mold construction, and large section runnerless molding. Adequate descriptions of valve gating, sequential impact molding, and insulated runner systems are included.

The author, in drawing from his personal experience in the processing of thermoplastics, describes these advancements towards fully automatic molding cycles.

This is a good book, well arranged, and covers topics of interest to novice or expert concerned with the conversion of thermoplastic materials into profitable items of commerce.

Raymond C. Cornelius
Plant Engineer
Armstrong Cork Company



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If you expect to attend the SPE Meeting in Washington, D. C. (Jan. 24-27) . . . drop in at Esso's suite in the Sheraton-Park Hotel. Members of our Technical Staff will be glad to discuss the significant research positions at Esso.

Forward replies in complete confidence to
Mr. C. D. Gardei, Professional Employment—Dept. U

Esso RESEARCH & ENGINEERING CO.
P.O. Box 175 • Linden, N.J.

Employment & Service Guide

POSITIONS OPEN

SALES REPRESENTATIVE

Experience in plastics essential, extrusion preferred for central and western Pennsylvania and West Virginia. Send full particulars, references to Box No. 162, SPE JOURNAL, Stamford, Conn.

SENIOR DEVELOPMENT CHEMIST

Opening exists for a Chemist or Chemical Engineer with experience in formulating thermosetting compounds, preferably with 2-8 years experience in formulating and evaluating molding compounds. This is an excellent opportunity to demonstrate creative abilities and to achieve advancement. Located in western New York State. Send resume to

T. H. Quinn
HYSOL Corp.
Olean, N. Y.

PLASTIC PLANT SUPERINTENDENT

Wanted – Superintendent of a well established injection and compression molding plant located in Northeast Ohio. Injection molding experience required. Salary commensurate with experience. Our employees know of this ad. Reply Box No. 161, SPE JOURNAL.

WANTED—TECHNICAL SALES REPRESENTATIVE

Manufacturer of Glass Reinforced Alkyd Molding Compounds offers excellent opportunity to aggressive young salesman in New England area. A knowledge of thermosetting molding compounds and molding experience is desirable. Mail resume to GLASKYD Incorporated, Eckel Road, Perrysburg, Ohio; Attention D. K. Welles.

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The newly created General Packaging Research and Development Division of Continental Can Co., devoted to the use of paper and plastics for packaging, require creative scientists to conduct research on the characterization of the mechanical, chemical and rheological properties of high polymers. Positions are open at all degree levels. Preference will be given to those candidates having two to five years of experience. These new positions will be located in the new Technical Center with modern equipment and facilities, offering an excellent opportunity for professional growth and personal advancement. Send confidential resumé to:

Personnel Supervisor
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4606 West Grand Avenue
Chicago 39, Illinois

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This work is concerned with applications research directed toward ultimate utilization as engineering materials for civilian and military communications applications.

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Send résumé to Director of Technical Employment, Department 815-J, Bell Telephone Laboratories, Murray Hill, New Jersey. Information will be held in confidence.

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The expanding and diversifying research effort at Electric Boat, leading designer and builder of nuclear submarines, has created a few opportunities in the Chemistry and Metallurgy section of the Research & Development Department. Advanced degrees are preferred.

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Requires 1 to 10 years experience in one or more of the following: polymer chemistry, urethane foams, elastomers.

Materials Application Development

Requires 4 to 10 years experience in one or more of the following: reinforced plastics, coatings, adhesives, foams.

General Plastics Engineering

Requires 1 to 10 years plastics background with strong leaning for mechanical design and process engineering.

Resumes are invited from creative Chemical Engineers with background as listed above. Please address Mr. Peter Carpenter.

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U.S.I. invites you to explore employment opportunities in the polymer field, in research, application development, and technical service. Our modern laboratories are located in Cincinnati and in the Champaign, Illinois, area.

INTERVIEWS at SPE CONFERENCE

Jan. 24-27—Washington, D. C.

For information or interviews on the following openings, call

MR J COUDOUX at ADAMS 4-0700

DEVELOPMENT ENGINEERS—for laboratory assignments in new product development and applications. Areas include formulation and application of resins coatings, fabrication techniques, and equipment design.

SERVICE ENGINEERS—to provide field customer service in polyethylene resin applications.

Requires experience in plastics fabrication, equipment design or application of resins for coatings and packaging.

SR. RESEARCH CHEMIST—Polymer or Physical Chemist, Ph.D., with 4 to 10 years experience in fundamental and applied polymer research. Requires proven ability in supervision, long range planning, and in evaluation projects.

Applicants not attending Conference may send resumes to:

U. S. INDUSTRIAL CHEMICALS CO.
Division of
National Distillers & Chemical Corp.
99 Park Ave., New York 16, N. Y.

PLANT MANAGER

National company seeks Plant Manager for large plastic extrusion plant. Broad experience plastic processing is a requirement. This is a permanent responsible position. Reply in confidence.

Box No. 169
SPE JOURNAL
65 Prospect St.,
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FILM SALES MANAGER

National company entering packaging film manufacture seeks film sales manager. Five years film sales experience minimum requirement. Once-in-a-lifetime opportunity for right man. All replies confidential.

Box No. 170
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65 Prospect St.,
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PLASTICS ENGINEERS

Immediate openings in our new Research and Technical Service Center for Engineers familiar with polymer evaluation. We require a Bachelor's Degree and 3 to 10 years experience in plastics processing, physical testing, and/or customer service, particularly in polyolefins and polystyrene. Employment will offer challenging opportunities in applications research, technical service and resin investigation. Location in pleasant suburban Northern New Jersey.
Please send detailed resume with salary history and requirements. All replies held in strictest confidence.

Reply to:
REXALL CHEMICAL COMPANY
Dept. KK
P. O. Box 37
Paramus, New Jersey

SALES ENGINEER

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Our expansion program provides an opportunity for an experienced man in our sales organization preferably with some knowledge of plastic extrusion.

All applications held in confidence. Please write giving experience, education & salary requirements to

E. R. Coddington,
Sales Manager

WALDRON-HARTIG

Division of Midland Ross Corp.

P.O. Box 531 Westfield, N. J.

CHEMIST OR CHEMICAL ENGINEER

Midwestern company has an opening for a chemist or chemical engineer with a minimum of 5 years experience in compounding and extrusion of thermoplastic resins. Please send resume and salary requirements to Box No. 165, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

POSITIONS WANTED

PLASTICS SPECIALIST

I work hard and accomplish a lot. My experience is heaviest in fiberglass reinforced polyesters, but I have received excellent training in thermoplastics and themosets in general. I seek an exceptional growth situation where creative thinking and hard work are rewarded. Box No. 174, SPE JOURNAL, 65 Prospect Street, Stamford, Conn.

PLANT MANAGER

Ten years experience in Injection and Compression molding. Knowledge of all phases of design, planning, quoting, production, finishing. Desire plant management position. Complete resume on request. Box No. 163, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

EXTRUSION EXECUTIVE

17 years experience. Currently directing technical department of multiplant PE film company. Seeking responsible management position in production or technical capacity. Thorough experience in rods, tubes, profiles, sheeting, film and extrusion coating. Working knowledge of all thermoplastics. Background experience includes process development and engineering, production supervision and new plant installations. Box No. 168, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

PLASTICS ENGINEER

Age 35. B.S., completing M.S. in chemical engineeering. Over 10 years experience in plant, production, and engineering management, process design, cost estimating. Extensive background reinforced plastics, thermoplastic, and thermoset coatings. Presently employed. Desire challenging manufacturing and/or engineering management position with east coast manufacturer. Resume furnished. Box No. 173, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

TECHNICAL SALES SERVICE REPRESENTATIVE

Chemist, M.S., eight years experience in the development of plastic, latex, and rubber compounds for commercial application. Background in sales, promotion, production, quality control, R & D, and administration. Familiarity with epoxies, polyesters, urethanes, vinyls, acrylics. Immediate availability. No geographical limitations. Reply Box No. 164, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

CHALLENGE WANTED

Registered engineer, age 33, 11 years varied experience injection molding/vacuum forming and heavy construction available February. I have sold services, products, and acted as purchasing agent, field engineer, expediter, chief estimator mold designer, plant manager and corporate treasurer. Reply Box No. 166, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

BLOW MOLDING ENGINEER

Plant Engineer M.E.; B.A.; M.B.A.; 35, 15 years exper. 5 years blow molding Machine, mold design, Plant Maintenance, production and Industrial engineering, management of 3 shift operation. Desires position plant engineer, plant manager of well established firm. Salary $13,000. Box No. 167, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

TECHNICAL SERVICE—ADMINISTRATION

Broad chemical specialty products and plastics R&D—formulation, evaluation, processing, applications. Present position technical director—supervision, production, purchasing. Desires responsible position where this experience may be utilized in working with people—technical service, lab administration, sales development.

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VERSATILE PLASTICS ENGINEER

Eighteen years responsible industrial experience: Supervision, research and development, production, liaison and administrative experience in thermoplastics and synthetic rubber. Desires managerial position involving plastics (polymer) research and development or general plant administration with a company located in the Eastern part of the U.S. Married, Family. Box No. 10060, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

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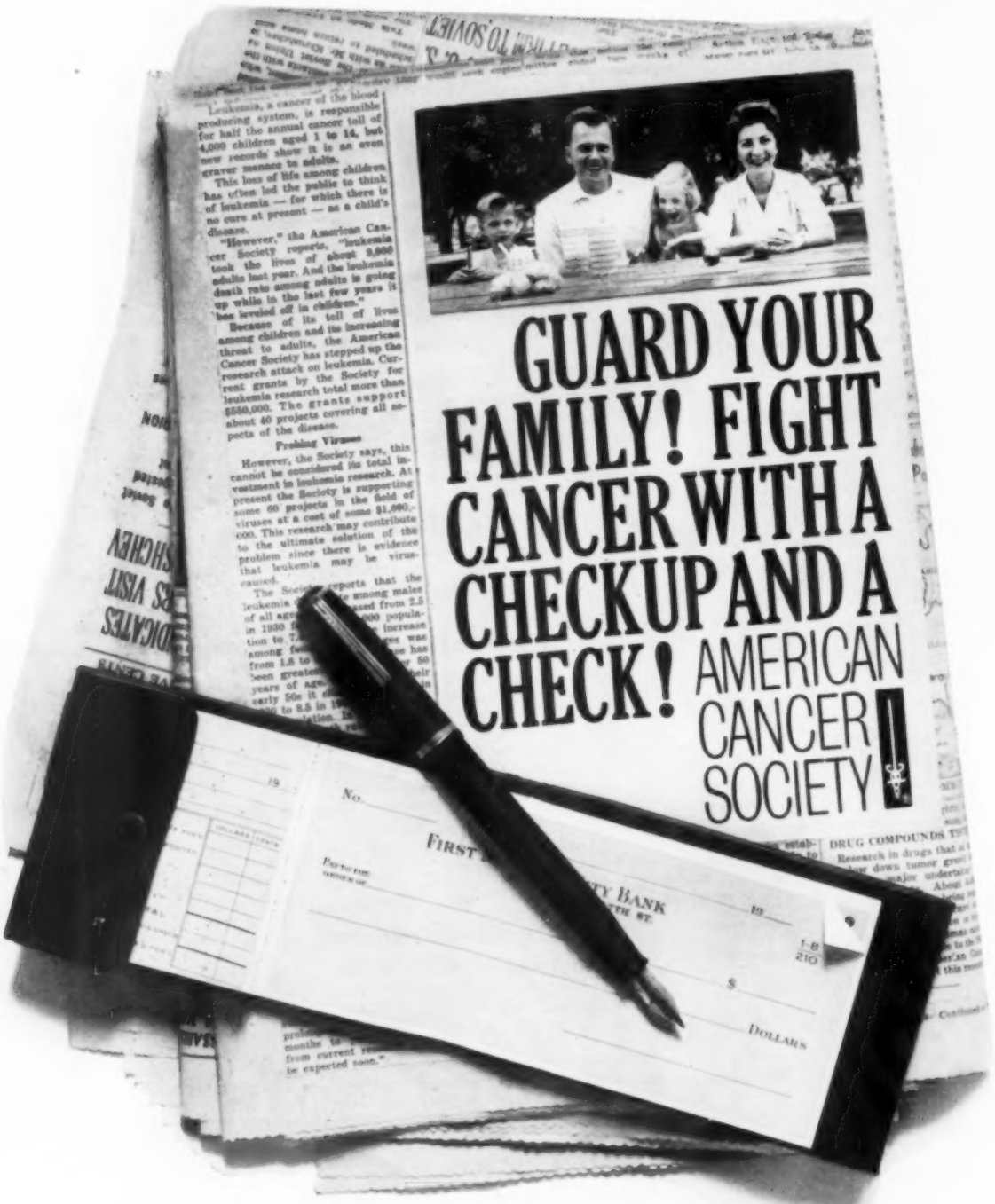
Last day for inserting ads is the first day of the month preceding date of publication. ***Employers please note: The SPE Journal does not have resumes on file. These must be requested from the applicant.***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